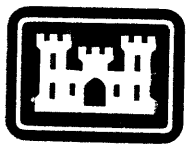
Baseline Public Health Assessment

Risk Assessment of the Building 3001 Site Tinker Air Force Base, Oklahoma



US Army Corps of Engineers

FINAL REPORT

August 1988

RISK ASSESSMENT OF

THE BUILDING 3001 SITE,

TINKER AIR FORCE BASE, OKLAHOMA

Installation Restoration Program
Project No. WWYK 86-311
Site I.D. No. OT01

prepared for

TINKER AIR FORCE BASE
OKLAHOMA CITY, OKLAHOMA

by

U.S. ARMY CORPS OF ENGINEERS
Tulsa District
P.O. Box 61
Tulsa, OK 74121-0061

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EXECUTIVE SUMMARY

This document is an assessment of the public health threat posed by chemical releases from the Building 3001 site to the regional groundwater aquifer. It is a baseline assessment which discusses and quantifies health risks if no action is taken to abate pollution at the site. Health risks were characterized for both carcinogens and non-carcinogens, using methodology recommended in USEPA's Superfund Public Health evaluation Manual.

The chemicals selected for detailed health evaluation were benzene, trichloroethene (TCE), tetrachloroethene (PCE), barium, chromium, lead, and nickel. These indicators were selected from 32 chemicals identified from the site as those that may pose the greatest risk to public health.

The assessment identified current and potential pathways of exposure and exposure points. The groundwater used by residents and the workforce of Tinker Air Force Base (AFB) was identified as a current pathway with the surface water of Soldier Creek to the east of the Building 3001 complex becoming a future pathway if no remedial action occurs. Contamination of the stream by infiltration of the perched groundwater was predicted. This infiltration will provide exposure routes of ingestion and inhalation to the population located along the stream.

Exposure concentrations were estimated using groundwater and air diffusion models. These exposure concentrations were compared to environmental standards and criteria, and except for TCE and nickel showed no violation of health standards. Estimates of human intakes were developed from predicted exposure concentrations and used to develop non-carcinogenic and carcinogenic risks. The intake values at each exposure point were compared to reported reference doses (subchronic and chronic) to determine additive effects. Additive effects of non-carcinogens were characterized by the hazard index (HI). An HI value of 1.0 indicated that non-carcinogenic health effects may occur within the exposed population.

The additive effects for carcinogens were characterized by multiplying the calculated intake by a reported carcinogenic potency factor for each potential carcinogen. Available information was not sufficient to assess synergistic effects (the combined effects of two of more chemicals exceed the additive effects of the individual chemicals). This is noted as one of several uncertainties which may underestimate health risks.

The hazard index indicated that subchronic (short-term) health effects were unlikely (HI<1.0) from consumption of Tinker AFB drinking water. The hazard index may indicate the potential for chronic (long-term) effects from both Tinker AFB drinking water (HI=1.18) and the long-term consumption of fish from Soldier Creek (HI=2.12). Additive effects by inhalation could not be quantified.

Carcinogenic health effects posed by benzene, TCE, and PCE in the groundwater varied by route specific exposures. Route-specific risks were calculated for groundwater and the surface water of Soldier Creek. These route-specific risks were summed for a conservative (upper-bound) estimate of risk. Acceptable risks are 10^{-5} to 10^{-7} or one additional incidence of cancer per 100,000 people to 10,000,000 people. The upper-bound carcinogenic risk for groundwater consumption at Tinker AFB (1.2×10^{-5} or 1 additional cancer/83,000 people) indicated possible health risks from long-term exposure. Carcinogenic risk from contamination of Soldier Creek by groundwater migration (6.9×10^{-6} or 1 cancer/145,000 people) was within acceptable risk values; therefore, carcinogenic responses for the exposed population would not be expected.

The remedial investigation detected an unidentified source of contaminants to the northeast of Building 3001. Contaminants from this source are similar in type to those from Building 3001, and are included in this risk assessment. Appendix G of this document quantifies risk to the exposed population from only the Building 3001 complex.

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PREFACE

Risk assessment is a relatively new and evolving methodology for evaluating the potential public health impact of uncontrolled hazardous waste sites, or for comparing the effects of various remedial action alternatives in reducing the threat to public health. Inherent in this methodology are numerous assumptions which require both knowledge and judgement by the preparer. The U.S. Environmental Protection Agency has published an important manual which details procedures for conducting public health evaluation; The Superfund Public Health Evaluation Manual. The preface of this publication contains an excellent discussion of the impact of judgement in the process:

"**Public health evaluation cannot be reduced to simple, 'cookbook' procedures.** If all judgment could be removed from the process, undoubtedly the results from various sites would be far more consistent. In addition, state-of-the-art public health evaluation techniques have not been fully accepted by all scientists, and import chemical data are frequently unavailable. For instance, toxicity testing has not kept pace with the need for information on many chemicals, and procedures used in exposure assessment often require many assumptions. The universe of uncontrolled hazardous waste sites is both variable and complex, with each site posing a unique set of circumstances. It would be unrealistic to expect that all data necessary to determine precisely the health risks associated with every site will be available. Where data gaps necessitate making assumptions to conduct the public health evaluation for a site, the manual instructs that all such assumptions be clearly documented. The manual is designed to be flexible, allowing the use of professional judgment. It is not a 'cookbook'. Instead, it provides a systematic process for evaluating potential public health impacts at a site and for documenting and supporting the assessment, its assumptions, and its conclusions."

"The manual provides a range of analytical procedures that may be needed at a particular site. It is up to the remedial project manager to determine the level of analysis required by using criteria discussed in

this manual. In addition, the manual contains a series of worksheets to assist in performing the public health evaluation. The worksheets are not intended to drive the evaluation, but to provide a consistent format for reporting results. **The results of the public health evaluation should be presented within the appropriate section of the RI/FS report."**

The qualifications of those preparing the Public Health Evaluation are critical because judgement on their part is integral to presenting a valid and defensible evaluation. The qualifications of the three individuals who prepared the Risk Assessment of the Building 3001 Site, and their primary contributions to the overall document are shown below.

David Combs has been an environmental specialist with both the Chicago District and the Tulsa District of the Corps of Engineers since 1984. His primary work with the Corps has involved environmental contaminant assessments, remedial investigation/feasibility studies, and remedial action strategies at Corps of Engineers civil works projects and at Defense installations within the two Corps Districts. Mr. Combs served as a research biologist in state government for 9 years prior to joining the Corps. He holds both BS and MS degrees in environmental studies from Eastern Kentucky University and is presently completing a MS degree in Environmental Engineering at Oklahoma State University. Mr. Combs is the author of a number of scientific papers addressing environmental issues, and has been a member of various State and Federal committees dealing with environmental problems. He served as study team manager in coordinating activities for the risk assessment at Building 3001, assisted in indicator chemical selection and assessment computations, and wrote all narrative in the report.

Ronald Coleman has been Chairman of the Department of Environmental Health at the University of Oklahoma Health Science Center since 1982. He received a BS degree from Abilene Christian College and a Doctor of Philosophy degree in biochemistry from the University of Oklahoma. Dr. Coleman's primary area of interest is environmental toxicology, and he has published 45 scientific papers in the field. Dr. Coleman was a professor within the Department of Environmental Health for several years before

becoming chairperson. He is a recognized expert in the field of environmental contaminants and has served on numerous local, state and federal committees. Dr. Coleman prepared the chemical data sheets and provided technical guidance in selection of the indicator chemicals and assumptions developed in the assessment. Dr. Coleman also served as principal reviewer of the assessment.

Richard Hunter has been Director of Environmental Health for Wichita and Sedgwick County, Kansas since October, 1985. For seven years prior to that, he was an environmental specialist with the Corps of Engineers. In that position he designed and managed programs, at Defense installations in Oklahoma and Arkansas, aimed at alleviating contamination from historical hazardous waste sites or permitting and managing hazardous waste operations under Federal and State laws. Mr. Hunter holds BS and MS degrees in Environmental Science from Oklahoma State University, and a Master of Public Administration from the University of Oklahoma. In addition, he is a Doctoral Candidate in Environmental Health at the University of Oklahoma. He has served on numerous environmental advisory committees to State and Federal Government, and is the author of 15 scientific papers on environmental contamination. Mr. Hunter is certified as a Hazardous Materials Manager by the Institute of Hazardous Materials Management. His primary expertise is in the area of movement of environmental contaminants and biostatistics. Mr. Hunter tabulated and performed statistical analyses on environmental data used in the risk assessment. He also was instrumental in the selection of indicator chemicals and calculation of exposure point concentrations.

The goal of this team throughout the risk assessment was to document the numerous assumptions which must be made when performing a risk assessment. By their nature, such assumptions are subject to challenge; however, each assumption used in this document represents a consensus of the members of the team preparing the assessment.

INTRODUCTION

GENERAL

In accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), an risk assessment has been prepared on a contaminant release to the environment from Building 3001, Tinker Air Force Base (AFB), Oklahoma. The document attempts to quantify the potential threat of the release to public health. The risk assessment represents a baseline assessment of public health impacts of the contaminant release in the absence of remedial action. This work is part of the U.S. Air Force Installation Restoration Program, and was performed by the Tulsa District Corps of Engineers.

This baseline health assessment evaluates the chemical contaminants of concern, the pathways of exposure, potential exposure concentrations, and characterization of risks resulting from exposure of chemicals released to the environment. The resulting baseline information will provide a basis for developing and evaluating remedial alternatives during the feasibility study. The characterization of health risks posed by evaluated contaminants may also provide a basis for developing treatment standards for site remediation.

The methodology used in developing the baseline public health assessment was based on guidance by the Environmental Protection Agency (USEPA, 1986) in the Superfund Public Health Evaluation Manual (SPHEM). The baseline assessment as described by SPHEM is a multi-step process in which:

- Chemicals at a site are identified and indicator chemicals are selected;
- Potential exposure pathways are characterized;
- Projected concentrations are compared to standards;
- Human intakes are estimated; and
- Toxicity is evaluated and risks are characterized.

The assessment initially describes the contaminant release site and current conditions as a basis for discussion of the health effects of the release. The assessment also describes and reports the results of the health assessment following the SPHEM methodology. Through each step of the assessment process, all quantification methods, assumptions, and decision processes are described to document the risk characterization developed. Appendices of raw data and health assessment worksheets developed in the quantification process (appendix F and C, respectively) are provided as documentation.

SITE DESCRIPTION AND NATURE OF PROBLEM

The contaminant release to the environment originated from the Building 3001 complex on Tinker Air Force Base. TAFB is located in central Oklahoma, in the southeast portion of the Oklahoma City metropolitan complex (figure 1). The Building 3001 site as described in the remedial investigation (USACE, 1987) includes the building complex, two adjacent underground storage tank areas, and the surrounding areas encompassed by the lateral extent of a groundwater contaminant plume. The site located near the northeast boundary of the base (figure 2) covers an area of approximately 220 acres.

The building complex houses aircraft overhaul and modification activities. Processes within the complex have generated organic solvents and metal wastes through degreasing, cleaning, and plating operations. Wastes generated from these operations escaped from underground storage pits and storm drains to the underlying soils and groundwater. Additional contamination of subsurface soils and groundwater has occurred as a result of fuel leakage from underground storage tanks to the north and southwest of Building 3001.

Releases of contaminants from these past activities have resulted in contamination of the groundwater beneath Building 3001 to a depth of approximately 170 feet. Although 32 organic and inorganic contaminants were identified in the groundwater during the remedial investigation

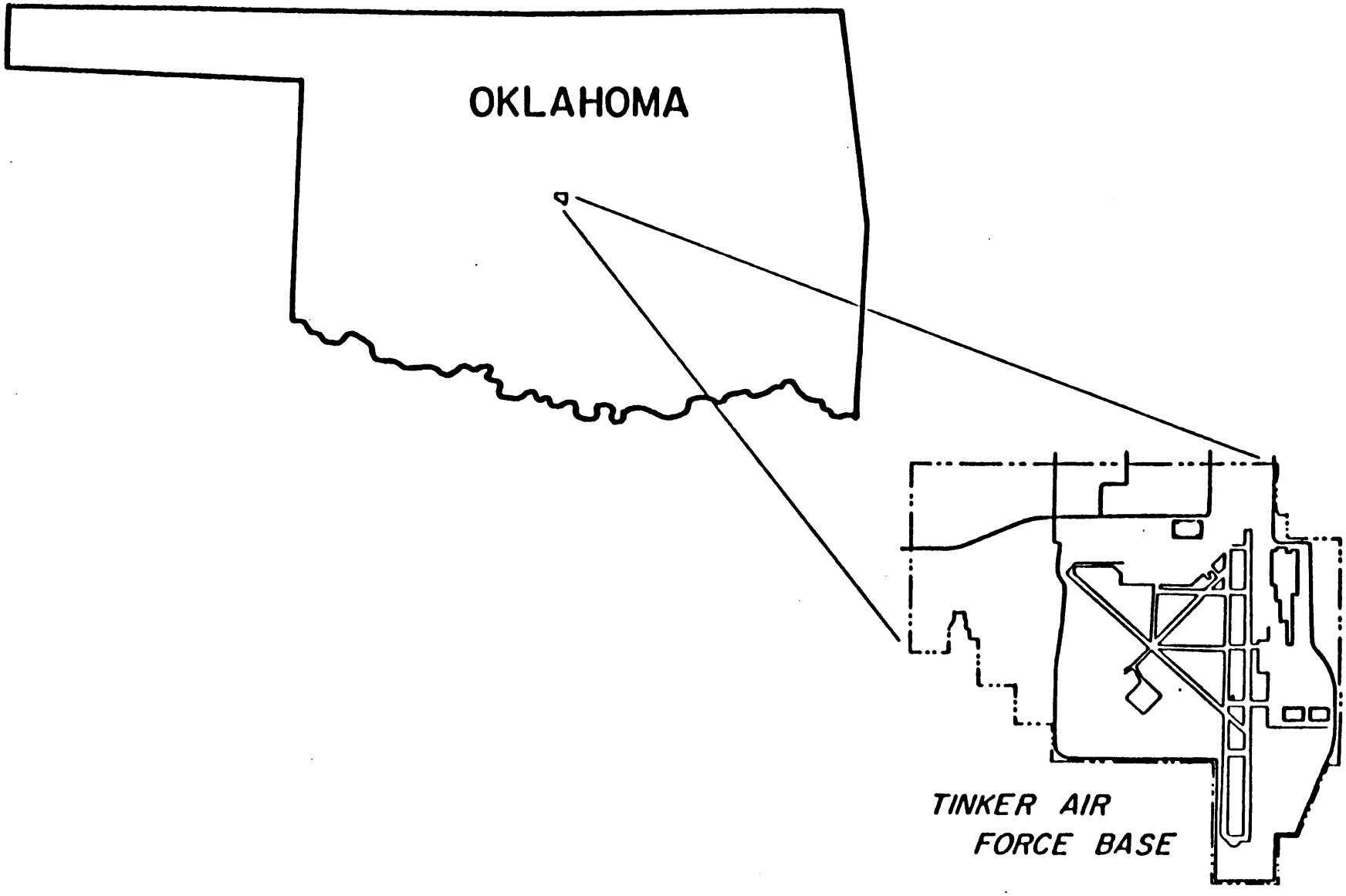

Figure 1. Location of Tinker Air Force Base within Oklahoma.

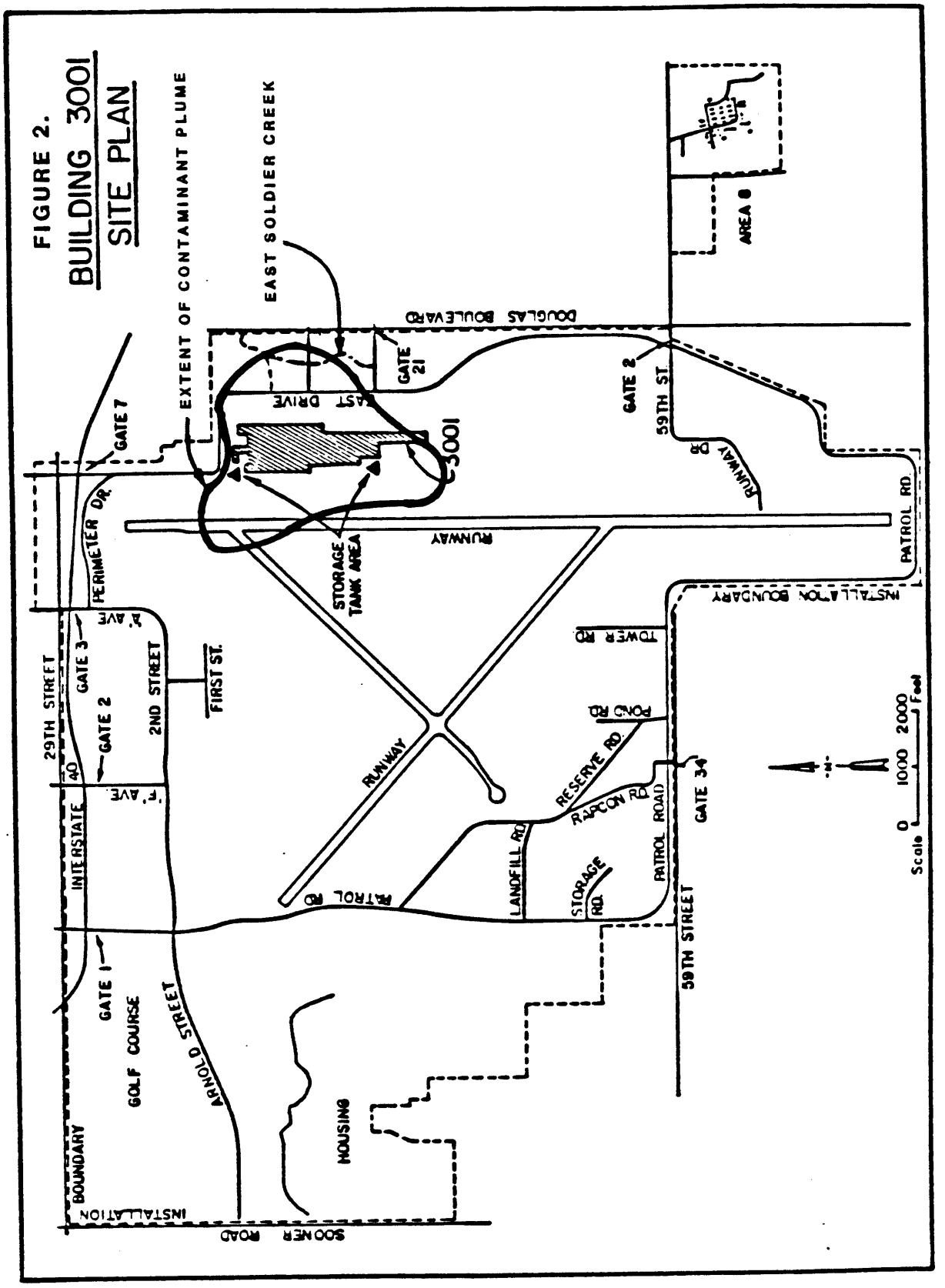
FIGURE 2.
BUILDING 3001
SITE PLAN
EXTENT OF CONTAMINANT PLUME
EAST SOLDIER CREEK
DOUGLAS BOULEVARD
GATE 21
EAST DRIVE
GATE 7
3001
GATE 2
59TH ST.
AREA B
RUNWAY DR.
RUNWAY
PERIMETER DR.
STORAGE TANK AREA
PATROL RD.
INSTALLATION BOUNDARY
TOWER RD.
POND RD.
RESERVE RD.
RAPCON RD.
GATE 34
PATROL ROAD
LANDFILL RD.
STORAGE RD.
PATROL RD.
59TH STREET
RUNWAY
29TH STREET
GATE 3
GATE 2
2ND STREET
FIRST ST.
INTERSTATE
40
F' AVE
GATE 1
GOLF COURSE
ARNOLD STREET
HOUSING
INSTALLATION BOUNDARY
SOONER ROAD
N
0 1000 2000
Scale Feet

(USACE, 1987), the primary contaminants, based on concentration and magnitude, are trichloroethene and chromium. The plume of these principal contaminants extends laterally across a subsurface area of 220 acres. The contaminated groundwater plume is presently located a maximum of 1,800 feet from Building 3001 and lies completely beneath the boundaries of Tinker AFB. As a result of the extensive groundwater pollution of the Building 3001 complex, the site was placed on the National Priorities List for cleanup.

The remedial investigation identified an additional contaminant plume originating northeast of Building 3001. The plume contains similar contaminants as those released from Building 3001 and is presently reaching water supply well number 16 along with contaminant migration from Building 3001. The source of this contaminant plume and its extent of groundwater contamination outside of the boundaries of the remedial investigation is presently unknown. Groundwater modeling conducted during the remedial investigation indicated that a major portion of the contamination predicted for well 16 would originate from the unknown source rather than from Building 3001. Health risks evaluated in this document are based on future predicted contaminant concentrations at exposure points (i.e., water supply wells) regardless of the source. The scope of the remedial investigations is being expanded to address the unknown source and its extent of contamination. An alternative analysis that assesses risks imposed only from the Building 3001 source is presented in Appendix G.

The remedial investigation identified that the contaminants exist in the subsurface soils beneath the building and documented migration into the perched aquifer and upper portions of the regional aquifer (Garber-Wellington). The regional aquifer supplies industrial and drinking water to Tinker AFB through a series of base water supply wells (figure 3) and to surrounding cities of the metropolitan area. The contaminant plume, at the present, has not migrated vertically into the water supply producing zone of the regional aquifer with the exception of two water supply wells around Building 3001 (wells 15 and 16).

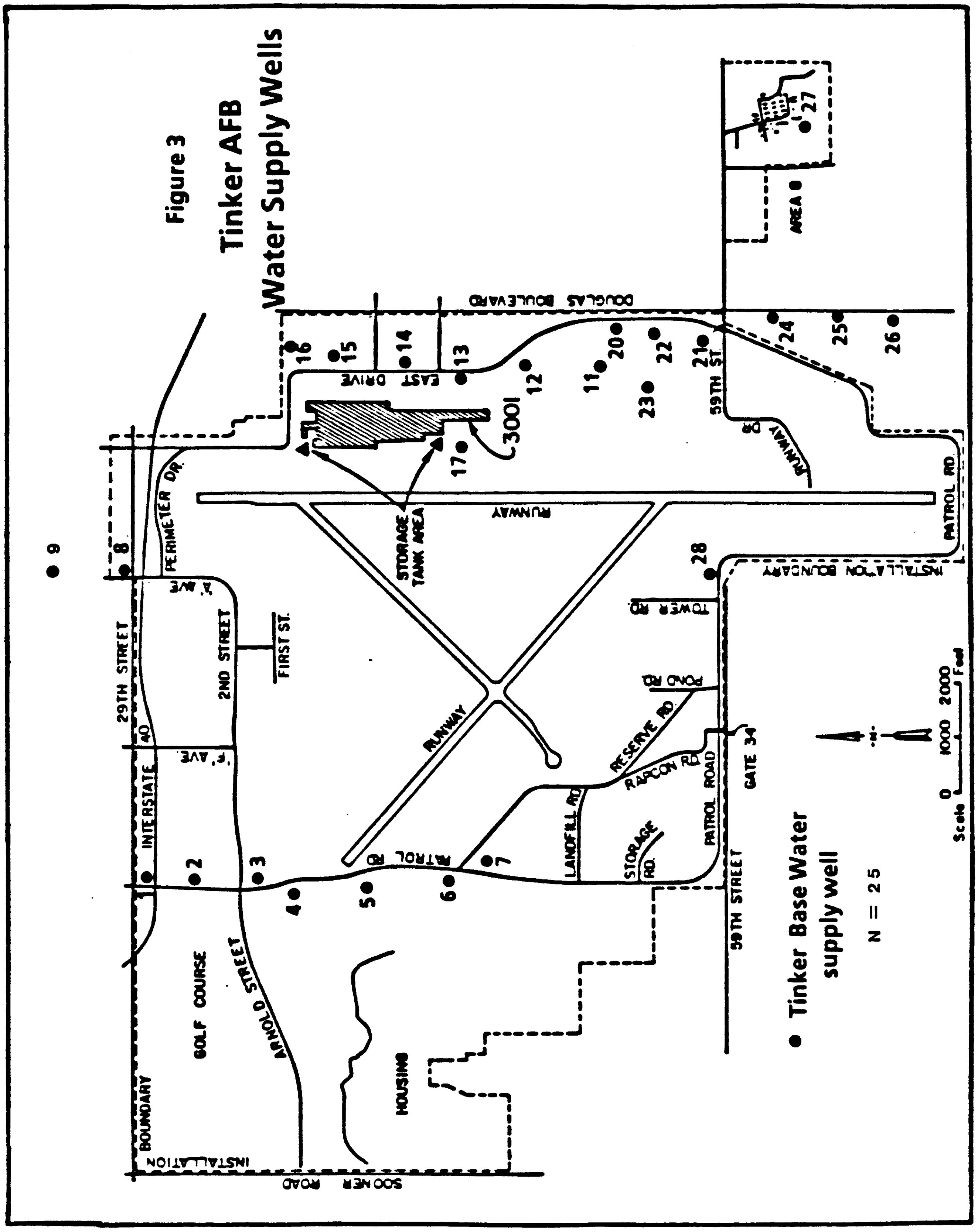
Figure 3
Tinker AFB
Water Supply Wells
Tinker Base Water supply well
N = 25
Scale 0 1000 2000 Feet
INSTALLATION BOUNDARY
SOONER ROAD
GOLF COURSE
ARNOLD STREET
HOUSING
INTERSTATE 40
29TH STREET
'F' AVE
2ND STREET
FIRST ST.
'A' AVE
PERIMETER DR.
PATROL RD
RUNWAY
STORAGE TANK AREA
3001
EAST DRIVE
DOUGLAS BOULEVARD
AREA B
59TH ST.
RUNWAY DR
PATROL RD
TOWER RD
POND RD
RESERVE RD
RAPCON RD
LANDFILL RD
STORAGE RD.
PATROL ROAD
GATE 34
59TH STREET
1
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Groundwater modeling conducted during remedial investigation by the U.S. Army Corps of Engineers indicates that the contaminant plume in the upper portions of the regional zone is moving to the west and southwest of Building 3001 away from the majority of Tinker AFB water supply wells with the exception of well 17. Although well 17 has not been sampled, it is predicted to be impacted by migration of the contaminants in the perched and regional aquifer at present and in the near future. The contaminant plume of the perched aquifer is expected to encompass wells 13 and 14 (figure 3) and possibly migrate to the upper zone of the regional aquifer. Although the producing zone will not be contaminated by the plume in the upper zone of the regional aquifer, wells encompassed by the plume of the perched aquifer (such as wells 13 and 14) may act as a conduit between the perched and producing zone of the regional aquifer. Future migration to the producing zone through additional conduits would expand the area of contamination in the aquifer used for drinking water supply and increase the health risks.

Public health concerns identified in the remedial investigation were based on the reported contamination of the Garber-Wellington aquifer. The aquifer is the primary source of water supply to Tinker AFB and the primary source of groundwater supply to the public in a seven-county area. Chemical contaminants degrading the quality of any portion of the regional water supply pose a potential threat to public health of the population using the contaminated water. Other concerns identified are based on the predicted migration of contaminated groundwater of the perched aquifer to Soldier Creek. This contamination of the surface water poses additional threats to aquatic organisms of the stream and to the public health of individuals in contact with the stream.

INDICATOR CHEMICAL SELECTION

Contaminants of the Building 3001 site were reported primarily in the groundwater media during the remedial investigation (USACE, 1987). Although the assessment was to be developed from chemicals detected in only one media, the number of chemicals was considered too large to quantify health risks. The remedial investigation identified 32 chemicals (24 organic and 8 inorganic) in the groundwater contaminant plume. The chemicals varied widely in occurrence and concentration with many chemicals detected too infrequently to evaluate as significant health risks. In an attempt to more effectively address the public health threat, the number of chemicals to be evaluated were limited to a manageable number of indicator chemicals. The EPA (1986) states in the SPHEM that indicator chemicals are to be based on those that pose the greatest potential health risk at the site. In accordance with methods described in SPHEM, a list of indicator chemicals was developed from the Building 3001 site to represent contaminants released to the environment posing the greatest public health risk. The following discussion describes the decision-making process and methodology in developing a list of indicator chemicals and reports the selection results.

INDICATOR CHEMICAL SELECTION METHODOLOGY

In the process of selecting indicator chemicals, general objectives of the indicator chemical list were developed to include chemicals that would:

- represent risks posed from organic and inorganic chemicals;

- represent both toxicological classes (carcinogenic and non-carcinogenic);

- represent compounds of greater toxicity, mobility, and persistence in the environment;

- include chemicals of significant concentrations and frequency in the groundwater contaminant plume; and

- include chemical contaminants from different release sources.

In order to meet the indicator list objectives, chemical data were screened for a compound's frequency of occurrence laterally at the site and vertically through the perched and regional aquifer. The reported concentrations of each chemical were also evaluated in relation to background values and drinking water standards. Chemicals not representing contamination in all three of the aquifers (perched, top regional, and regional) described in the remedial investigation were eliminated from further evaluation.

Chemicals detected at a low frequency of occurrence (<20%) were eliminated from further consideration. Chemicals at or below background values or drinking water standards were also eliminated during the screening process. Chemicals that exceeded background or standard in less than twenty percent of the samples were not carried onto the indicator scoring process.

Contaminants not eliminated during the screening process were compared to each other through numerical values developed in an indicator score algorithm. The algorithm uses the maximum and/or mean concentration of each chemical multiplied by a media specific toxicity constant reported for individual chemicals, as follows:

$$CT = \text{Concentration (C)} \times \text{Toxicity Constant (T)},$$

using the mean value of TCE in groundwater as an example:

$$CT_{MAX} = 10.283 \text{ mg/l} \times 4.29E\text{-}03 \text{ l/mg} = 4.4E\text{-}02$$

The mean concentration was considered as a representative concentration in the groundwater media with values expressed as representative throughout

the report. When toxicity constants were not available for chemicals in specific pathways, a constant was derived from acceptable intake, chronic data (AIC) or the selection process for that chemical was based on other factors of frequency, toxicity, and mobility.

Indicator scoring methods and toxicity values are those described in the SPHEM. Chemicals tentatively ranked by score for each toxicological class were evaluated for their physical and chemical properties of toxicity and mobility to provide indicator chemical selection. Some of the factors used to evaluate these properties included:

Vapor pressure - A relative measure of the volatility of a chemical in its pure state.

Henry's Law Constant - An estimator of volatility which combines vapor pressure, solubility and molecular weight.

Organic carbon partition coefficient (K_{OC}) - a measure of relative sorption potential which indicates the tendency of an organic chemical to be adsorbed to soil or other solid matrices.

In addition to the indicator scoring process, predicted groundwater concentrations over a 70-year release period generated through groundwater modeling were used in the final evaluation of indicator chemicals.

INDICATOR CHEMICAL SELECTION RESULTS

The chemicals detected in the groundwater plume, their frequency of occurrence, and concentration are shown in table 1. Of the 32 chemicals identified in the groundwater, one-half occurred infrequently (i.e. were detected in less than 20 percent of the samples). Many of these chemicals were detected vertically in only portions of the aquifer, rather than in all three aquifers as required by the screening protocol. As stated previously, these chemicals were eliminated from further analysis in favor of more ubiquitous contaminants. Comparison of reported concentrations of

TABLE 1. Summary of the Frequency of Occurrence and Concentrations of Chemical Constituents Identified in Groundwater Below Building 3001, Tinker AFB.

Chemical (CAS)	Frequency (% Occur.)	Concentration (ug/l) Range	Mean	Number of Aquifers Present
Acetone (67-64-1)	27/93 (29.0)	16-1,600	320.9	3
Benzene (71-43-2)	17/98 (17.3)	1-7,946	871.7	3
1,2 Dichlorobenzene (95-50-1)	1/75 (1.3)	12	12	1
1,1 Dichloroethane (75-34-3)	1/75 (1.3)	3	3	1
1,2 Dichloroethane (107-06-2)	10/75 (13.3)	3-390	86.3	3
1,1 Dichloroethene (75-35-4)	6/75 (8.0)	1-16	10.5	3
Trans-1,2 Dichloroethene (540-59-0)	38/73 (52.1)	5-4,600	295.6	3
1,2 Dichloropropane (78-87-5)	1/75 (1.3)	36	36	1
Methylene chloride (74-87-3)	12/53 (22.5)	6-170	36.1	3
Carbon tetrachloride (56-23-5)	2/75 (2.7)	5-14	9.5	2
Chlorobenzene (108-09-7)	8/71 (11.3)	6-940	140.8	3
Chloroform (67-66-3)	4/75 (5.3)	5-48	17.5	2
1,1,2,2 Tetrachloroethane (79-34-5)	3/75 (4.0)	19-460	167.7	2
Tetrachloroethene (127-18-4)	16/67 (23.9)	2-1,200	164.4	3
Vinyl chloride (75-01-4)	6/75 (8.0)	4-530	116.2	3
Xylenes (1330-20-7)	14/96 (14.6)	6-2,150	451.9	3
Toluene (108-88-3)	19/94 (20.2)	1-41,715	7305.03	3
1,1,1 Trichloroethane (71-55-6)	6/67 (9.0)	5-100	43.6	3
1,1,2 Trichloroethane (79-00-5)	1/75 (1.3)	60	60	1
Trichloroethene (79-01-6)	49/75 (65.3)	5-330,000	10,283.3	3
Phenol (108-95-2)	2/75 (2.7)	38-86	62	1
Bis (2 ethylhexyl) phthalate (117-81-7)	8/75 (10.7)	7-1,300	188.9	3
Di-butyl phthalate (84-74-2)	3/75 (4.0)	31-300	124.7	1

TABLE 1. Summary of the Frequency of Occurrence and Concentrations of Chemical Constituents Identified in Groundwater Below Building 3001, Tinker AFB - Continued.

Chemical (CAS)	Frequency (% Occur.)	Concentration (ug/l) Range	Mean	Number of Aquifers Present
Di-n-octyl Phthlate (117-84-0)	1/75 (1.3)	37	37	1
Arsenic (7440-38-2)	60/84 (71.4)	1-58	8.4	3
Barium (7440-39-3)	77/93 (82.8)	500-27,000	3,150.6	3
Cadmium (7740-43-9)	38/84 (45.2)	8-15	10.5	3
Chromium VI* (7440-47-3)	55/76 (73.3)	10-120,000	3,843.1	3
Lead (7439-92-1)	60/68 (88.2)	25-580	105.0	3
Nickel (7440-02-0)	81/81 (100)	13-1,900	183.2	3
Mercury (7439-97-6)	10/67 (14.9)	0.1-0.7	0.3	3
Selenium (7782-49-2)	31/74 (41.9)	0.4-6.0	1.4	3

* denotes that all chromium was assumed to be hexavalent.

contaminants in the groundwater to background values and drinking water standards eliminated four metals from further consideration as indicators. During the screening, two additional compounds were eliminated based on judgmental values. Justification for eliminating specific chemicals as potential indicators of risks associated at the site is discussed in following paragraphs.

The remaining ten chemicals (6 organic and 4 inorganic) were carried through the indicator scoring process as described previously. The chemicals selected for further evaluation were benzene, trichloroethene, toluene, trans-1,2 dichloroethene, methyl chloride, tetrachloroethene, barium, chromium, nickel, and lead. As stated, these chemicals represent those found in the highest frequency, those representing both carcinogens and non-carcinogens, and those of relatively greater mobility and toxicity. Indicator scores of these chemicals (tables 2 and 3) provided the basis for final selection. Of the ten chemicals evaluated, seven were selected as indicator chemicals for detailed evaluation of exposure assessment and risk characterization. The basis for final chemical selection and the list of selected indicator chemicals is discussed in the following paragraphs.

Chemicals Eliminated

The chemical data presented in the remedial investigation report represented both dissolved and total metal concentrations in the groundwater. The sample size for total metal concentrations was much greater than for dissolved metals; therefore, dissolved concentrations were rejected and not used in the indicator chemical selection or health assessment process. Total metal values were greater and, thereby, providing a more conservative estimate of concentrations for the subsequent exposure assessment. In addition, background values reported and used for comparison were total metal concentrations.

TABLE 2. Scoring for Indicator Chemical Selection: Calculation of CT[a] and IS[b] Values for Carcinogenic Effects.

Chemical	Ground Water CT[a]		Surface Water* CT		Soil* CT		Air* CT		IS[b] Value		Tentative Rank	
	Max	Rep	Max	Rep	Max	Rep	Max	Rep	Max	Rep	Max	Rep
Trichloroethene	1.4E+00	4.4E-02	-	-	-	-	-	-	1.4E+00	4.4E-02	1	1
Tetrachloroethene	1.1E-02	1.4E-03	-	-	-	-	-	-	1.1E-02	1.4E-03	2	2
Benzene	6.1E-02	6.7E-03	-	-	-	-	-	-	6.1E-02	6.7E-03	3	3
Methylene Chloride	-	-	-	-	-	-	-	-	-	-	4	4

* Contaminants were not reported in other media.
a denotes product of concentration x toxicity constant
b denotes indicator score

TABLE 3. Scoring for Indicator Chemical Selection: Calculation of CT[a] and IS[b] Values for Noncarcinogenic Effects.

Chemical	Ground Water CT[a]		Surface Water* CT		Soil* CT		Air* CT		IS[b] Value		Tentative Rank	
	Max	Rep	Max	Rep	Max	Rep	Max	Rep	Max	Rep	Max	Rep
Barium	1.1E+02	1.3E+01	-	-	-	-	-	-	1.1E+02	1.3E+01	1	1
Trichloroethene	3.5E+02	1.1E+01	-	-	-	-	-	-	3.5E+02	1.1E+01	2	2
Nickel	8.1E+00	7.8E-01	-	-	-	-	-	-	8.1E+00	7.8E-01	3	3
Benzene	9.3E-01	1.0E-01	-	-	-	-	-	-	9.3E-01	1.0E-01	4	4
Lead	5.2E-01	9.4E-02	-	-	-	-	-	-	5.2E-01	9.4E-02	5	5
Toluene	2.4E-01	3.8E-02	-	-	-	-	-	-	2.4E-01	3.8E-02	6	6
Trans-1,2 Dichloroethene	2.4E-01	1.6E-02	-	-	-	-	-	-	2.4E-01	1.6E-02	7	7
Methyl Chloride	1.5E-02	3.3E-03	-	-	-	-	-	-	1.5E-02	3.3E-03	8	8
Tetrachloroethene	1.2E-02	1.6E-03	-	-	-	-	-	-	1.2E-02	1.6E-03	10	9
Chromium VI	-	-	-	-	-	-	-	-	1.4E-02	4.4E-04	9	10

* Contaminants were not reported in other media.
[a] denotes product of concentration x toxicity constant
[b] denotes indicator score

Chemicals that were rejected because of low frequency were 1,1 dichloroethane, 1,1 dichloroethene, 1,2 dichloroethane, chlorobenzene, 1,1,1 trichloroethane, vinyl chloride, 1,1,2,2 tetrachloroethane, 1,2 dichlorobenzene, 1,1,2 trichloroethane, chloroform, 1,2 dichloropropane, carbon tetrachloride, phenol, bis (2 ethylhexyl) phthalate, di-n-butyl phthalate, and di-n-octyl phthalate. Many of these organic compounds were detected only once in the sampling program. Others appear to be degradation products which would account for lower incidence at the present time.

Contaminants eliminated due to low concentrations were arsenic, cadmium, mercury, and selenium. Arsenic was detected at a high frequency of occurrence in the groundwater plume (71%) through all vertical layers of the groundwater. Although fairly ubiquitous and above background, only one arsenic value was greater than the Safe Drinking Water Act (SDWA) standard of 50 ug/l. At the reported levels, health risks are already below those set by the standard; therefore, arsenic was rejected as an indicator chemical. Cadmium was also rejected because the reported values only slightly exceeded the SDWA standards of 10 ug/l. Cadmium was also rejected because of its low incidence in the groundwater in relation to other metals that could represent similar health effects. Mercury was rejected because its representative (mean) value was below background levels and its low incidence in the groundwater (15%) in relation to other metals. Selenium was eliminated from final consideration because the concentrations were at or below background levels through most of the aquifers. Selenium was also at concentrations below SDWA standards of 10 ug/l. As with arsenic, the standard has been set to protect public health with health risks being acceptable at or below that concentration.

Acetone and xylene (total xylenes) were rejected from consideration as indicator chemicals in favor of other organics based on professional judgments. These included the fact that acetone is typically used as a cleaning solvent in the field and the concentrations reported may be an artifact of residual acetone in the sampling equipment. Because the presence of acetone is possibly a reflection of equipment concentrations,

it was rejected as an indicator in favor of other organic contaminants. Xylenes are one of three major contaminants resulting from fuel contamination of the groundwater at the Building 3001 site. The indicator list was to include a component of BTX to represent contamination from the fuel area; however, xylenes were rejected because of a lack of information on health effects in favor of benzene and toluene with similar distribution and better defined health effects.

Chemicals eliminated during indicator scoring procedures were methylene chloride, trans-1,2 dichloroethene, and toluene. The three organic compounds were rejected based on their indicator scores for non-carcinogenic effects (table 3). Toluene was rejected because benzene provided a better representative chemical in the BTX contamination. Methylene chloride was rejected in favor of organics of similar absorption characteristics to soil expressed as octanol-carbon coefficients (K_{OC}), density, mobility, and greater occurrence in the groundwater.

Chemicals Selected

Selection of the indicator chemicals was determined by the magnitude of the indicator scores and evaluation of the chemicals fate and transport characteristics (table 4). Representative indicator scores were used in the chemical score comparisons. However, the maximum and minimum scores showed little change in the overall ranking of chemicals. Justification of indicator chemical selection follows:

Benzene. Benzene was selected as an indicator chemical because it is a human carcinogen with a weight of evidence rating of A (Appendix A). Benzene was also selected based on its indicator scores (table 4). Benzene had moderate indicator scores for carcinogenic effects and potential non-carcinogenic effects. Physical and chemical information indicated that benzene was relatively mobile in the environment. Benzene was also representative of the BTX contamination from the underground fuel tanks with a higher non-carcinogenic indicator score (1.0E-01) than toluene (3.8E-02).

TABLE 4. Scoring for Indicator Chemical Selection: Evaluation of Exposure Factors and Final Chemical Selection.

Chemical	IS Values* PC[1]	IS Values* NC[2]	Ranking PC	Ranking NC	Water Solubility (mg/l)	Vapor Pressure (mmHg)	Henry's Law Constant ($atm-m^3/mole$)	K_{OC}	Half-Life Days GW[3]	Half-Life Days SW[4]	IC[5]
Trichloroethene	4.43+01	1.1E+01	2	3	1,100	58	9.10E-03	126	-	90	+
Barium	-	1.3E+01	-	1	-	-	-	-	-	-	+
Chromium VI	-	4.4E-04**	-	1	-	-	-	-	-	-	+
Nickel	-	7.8E-01	-	4	-	-	-	-	-	-	+
Benzene	6.9E+00	1.0E-01	1	5	1,750	95	4.49E-03	83	-	6	+
Lead	-	9.4E-02	-	6	-	-	-	-	-	-	+
Toluene	-	3.8E-02	-	7	535	28	6.37E-03	300	-	14	
Trans-1,2 Dichloroethene	-	1.6E-02	-	8	6,300	324	6.56E-03	59	-	6	
Methyl Chloride	N/A	3.3E-03	-	9	6,500	4,310	4.40E-02	35	-	10	
Tetrachloroethene	1.4E-03	1.6E-03	3	10	150	18	2.59E-02	364	-	30	+

* Based on representative concentrations

** IS Value estimated from AIC divided by 70kg person as the toxicity constant

\+ indicates selection as indicator chemical

NA denotes that IS values were not computed because a toxicity constant was not reported.

1. Denotes IS value based on potential carcinogenic effects by oral route.
2. Denotes IS value based on potential non-carcinogenic effects by oral route.
3. Denotes groundwater.
4. Denotes surface water.
5. Denotes indicator chemical.

Trichloroethene (TCE). TCE is a probable human carcinogen with a weight of evidence rating of B2. TCE was selected based on its high indicator scores for both carcinogen and non-carcinogen effects, ranking number two in the potential carcinogenic and number three in the non-carcinogenic category (table 4). TCE was also the most significant contaminant identified in the remedial investigation sampling with a high frequency of occurrence in all aquifer layers and the highest concentrations reported in the study (330,000 ug/l). Physical and chemical information confirms that TCE is a highly mobile contaminant in the environment.

Tetrachloroethene (PCE). PCE was selected because it is a possible human carcinogen with a weight of evidence rating of C. This is a change in the weight of evidence rating which was recently made from B2 to C after a recommendation by the Science Advisory Board Environmental Health Committee (letter dated January 27, 1987). Although PCE's non-carcinogen indicator score was low (table 4), it was selected over trans-1,2 dichloroethene, toluene, and methylene chloride because of its toxicological classification. The chemical and physical data on PCE indicates that it represents an organic compound of lower mobility but relatively higher persistence as evidenced by K_{OC} values.

Chromium. Chromium in this health assessment was assumed to be all hexavalent chromium. The remedial investigation reported that most of the chromium detected was hexavalent. Hexavalent chromium is a greater health threat than other chromium species (appendix B). As a conservative estimate of health risks, all non-speciated chromium reported in the remedial investigation was evaluated as hexavalent. Chromium was selected based on its high frequency of occurrence and concentrations. Chromium had the highest concentration of inorganic constituents (120,000 ug/l). Chromium in a water media is not an oral carcinogen; therefore, it was scored for only non-carcinogenic effects. An oral toxicity constant was derived for chromium from the acceptable daily intake (chronic) value reported in the SPHEM (exhibit A-6). The calculation involved taking the AIC (5.00E-03 mg/kg/day) and converting it to $(mg/l)^{-1}$ as required by the

SPHEM (exhibit 3-2). This conversion was accomplished by first dividing the AIC by the average adult body weight of 70 kg, producing a value of 7.143E-05 mg/day. This value was then multiplied by the amount of water consumed per day by an adult, 2 l/day, to obtain a toxicity constant of 1.43E-04 mg/l. Based on this value, the indicator score for a non-carcinogen was extremely low. However, because of its potential hazard as hexavalent chromium and the high concentrations in the contaminant plume, it was selected as an indicator chemical.

Barium. Barium was selected because of its high indicator score as a non-carcinogen (table 3). Barium was detected in a high frequency of occurrence in the groundwater and at concentrations well over background values and the drinking water standards of 1,000 ug/l. The toxicological effects of barium, like chromium, are dependent upon the form of barium found in the groundwater (appendix B). As a conservative approach, the form of barium was assumed to be the more toxic soluble forms. The severity rating for barium (appendix A) is 10. Therefore, barium was included as an indicator chemical.

Lead. Lead was selected as an indicator chemical because of its indicator score as a non-carcinogen. Lead was also detected in the groundwater at a high frequency occurrence and at concentrations well above the drinking water standard (50 ug/l). Lead's known toxicological effects (appendix B) also provided the basis for inclusion as an indicator chemical.

Nickel. Nickel was selected as an indicator chemical based on its indicator score as a non-carcinogen (table 3). Nickel, like chromium, is a carcinogen through an inhalation route but has only non-carcinogenic effects through ingestion. The severity rating for nickel is 3 (appendix A). Nickel was found in 100% of the samples taken during groundwater sampling. Concentrations of nickel ranged from 13 to 1,700 ug/l, with a mean of 183 ug/l. Although no standard exists for nickel, a guidance level of 150 ug/l (50 FR 46936, November 13, 1985) has been reported with the concentrations in the groundwater generally exceeding the guideline (appendix B).

The final indicator list (table 5) satisfies the indicator selection objectives by representing both organic and inorganic contaminants, carcinogens and non-carcinogens, releases from both the Building 3001 complex and the fuel area, and representative of chemicals of a greater toxicity and mobility risk identified at the site. These indicator chemicals were evaluated for exposure pathways, exposure concentrations, human intakes, and characterization of risks in subsequent sections of the assessment.

TABLE 5. Indicator Chemicals Selected for Risk Evaluation

Chemical
Benzene (C)
Trichloroethene (PC)
Tetrachloroethene (PC)
Barium
Chromium VI
Lead
Nickel

C denotes known carcinogen
PC denotes potential oral carcinogen

EXPOSURE ASSESSMENT

The following exposure assessment identifies known and potential pathways of contaminant exposure as well as the various routes of exposure, the potentially exposed population, and the expected chemical concentrations at each exposure point. Concentrations were compared to appropriate or relevant and applicable environmental requirements (ARARs) prior to developing human intake values and health risks. The National Contingency Plan, a document EPA prepared in response to CERCLA, established and defined ARARs. At present, EPA considers drinking water maximum contaminant levels, maximum contaminant level goals, federal ambient water quality criteria, national ambient air quality standards, and state environmental standards to be potential ARARs.

EXPOSURE PATHWAY ANALYSIS

As described in the SPHEM, the necessary elements of an exposure pathway are sources of contamination, a transport medium, routes of exposure, and human receptors at exposure points. The contaminant release at the Building 3001 site has all the elements for analysis of contaminant pathways. These elements are described in the following sections.

Identification of Exposure Sources

Sources of contamination were identified in the site remedial investigation as the subsurface soils of the Building 3001 complex and the north and south fuel areas. Surface soils of the fuel areas were not contaminated because the release was from underground tanks. Contaminated soils are not directly in contact with the atmosphere for volatilization; however, volatilization of fuel components is possible from subsurface soils to the atmosphere. The contaminated soils of the Building 3001 complex are those directly underneath the building, effectively segregating the soils from the surface and direct human contact. The subsurface soils of the site have contaminated the groundwater through

seepage. This vertical migration has resulted in the contamination of the shallow perched aquifer and upper portions of the regional (Garber-Wellington) aquifer.

The contaminant release from subsurface soils at the Building 3001 site have presently contaminated only groundwater (table 6). Contamination of other transport and release media (air, surface soil, and surface water) as a result of the uncontrolled contaminant release from the Building 3001 site were not identified in the remedial investigation.

TABLE 6. Preliminary Release Source Analysis for Baseline Site Conditions.

Release/ Contact Medium	Currently Contaminated	Potential Release Sources	Release Mechanisms	Release Time Frame	Release Likelihood and Amount
Air	No	Contaminated surface water	Volatil-ization	Continuous long-term	Probable low
Surface Water	No	Contaminated groundwater	Seepage	Continuous long-term	Definite moderate
Ground Water	Yes	Contaminated subsurface soil	Percol-ation	Continuous long-term	Definite moderate
Surface Soil	No	None-See Note 1			

Note 1 - Only subsurface soil is contaminated. No further consideration of surface soil as a release/contact medium or source.

Identification of Exposure Routes

The contaminated groundwater is composed of two distinct aquifers (perched and regional) providing different pathways for exposure. In the absence of remedial action, the regional aquifer used as a source of water supply will provide a long-term continuous source of contamination for wells 15, 16, and 17 (figure 3). Well 17 was not sampled during the remedial investigations because the well was out of service and access was

not possible (USACE, 1987). However, due to the well location with respect to the contaminant plume, it is assumed to be contaminated. The perched aquifer contaminant plume may increase the number of municipal water wells on Tinker AFB that are potential exposure points. Although the plume of the regional aquifer is not expected to migrate into the producing zone of wells 13 and 14, the wells may become contaminated in the future from the perched aquifer. The contaminant plume of perched aquifer presently encompasses an area including wells 13 and 14. These wells may act as conduits for contaminants between the perched and regional aquifers. Should contamination of wells 13 and 14 occur from the perched aquifer, the number of wells providing exposure points for users of municipal water supplies will increase. The continued release of contaminants from the subsurface soils to and through the groundwater provides an exposure point at the residences and workplaces on Tinker AFB. Routes of exposure from contaminated drinking water are ingestion, dermal contact, and inhalation from showers and industrial processes. Ingestion was considered the most significant route potentially affecting (for purposes of this conservative risk assessment) all workers and residents at the installation. Dermal and inhalation routes were considered to affect primarily full time installation residents rather than the workforce population.

The perched aquifer lying directly below contaminated subsurface soils will continue to receive and transport contaminants to the underlying regional aquifers and in the future transport contaminants to the surface water (Soldier Creek) within the northeast boundary of Tinker AFB. Water supply wells in the perched aquifer in this area are not common. A survey conducted by the Oklahoma City-County Health Department (Mr. Jim Armstrong, personal communication) around Tinker AFB reported no wells using the perched water for consumptive or non-consumptive uses. Therefore, the perched aquifer as a water supply source was dropped from pathway analysis.

The contaminated perched groundwater is predicted to release contaminants to surface water through seepage up through the stream. The groundwater will therefore provide a chronic source of contamination of

the stream. Once contaminated groundwater reaches the stream, the stream provides a second transport media and expands the exposure pathway to local, off-installation populations. Routes of exposure from the contaminated surface water are; inhalation of organic contaminants released through volatilization, ingestion, and dermal contact with the stream. The route of ingestion was assumed to be consumption of fish from the stream and possibly incidental ingestion of water during recreational activities; no other routes of ingestion could be postulated. The waters of Soldier Creek and Crutcho Creek downstream are untreated, and therefore do not represent a bacteriologically safe drinking supply source. Therefore, ingestion of contaminated water was not considered as a significant route of exposure.

Volatilization of organic contaminants from the surface waters to the air was considered a probable release mechanism. Therefore, inhalation is an exposure route (table 6). Volatilization was assumed to provide a chronic mechanism for release and exposure to low concentrations. This assumption is based on the fact that the organic indicator chemicals are volatile and flow turbulence in the surface waters is generally sufficient to liberate these volatile chemicals.

Identification of Exposed Population

The potentially exposed population, or receptors of contaminants released from the Building 3001 site, is discussed as presently exposed populations. This is because of the use of water supply wells within the contaminant plume, and the conservative basis of the risk assessment. Those same receptors are discussed as future exposed populations because the additional contamination pathways of surface water and air will occur from perched water transport and release to Soldier Creek.

The Building 3001 site is located on Tinker AFB, which has a workforce population of approximately 20,000 and a resident population of 2,500 (USACE, 1987). At the present time, the workforce and resident populations represent the potentially exposed population. Contamination of water supply wells 15, 16, and 17 completes the exposure pathway for

on-base personnel. These contaminated wells are assumed (following the conservative logic of this risk assessment) to be part of the water supply system that provides drinking and industrial water throughout the installation. Water from contaminated wells is blended with the waters of additional base wells (25 total wells) to serve the installation. The workforce would be exposed through ingestion of water and possibly inhalation of contaminants released during industrial processes during working hours. The residential population would have essentially full-time exposure through ingestion of drinking water and inhalation and dermal exposure through showering. Sensitive populations at risk on the installation are patients in the base hospital and children of base residents. No attempts were made to quantify these sensitive populations because patients at the base hospital and children living on base both represent relatively transient populations.

Potentially exposed populations increase once the surface water becomes contaminated. At that future time, the residential and business communities along Soldier Creek become part of the exposed population in addition to that of Tinker AFB. The Building 3001 site is bordered to the north by Midwest City and to the northwest by Del City, with populations of 58,000 and 33,400 (1980 Census), respectively. Although these cities border the contamination site and use the regional aquifer for water supply, the potentially exposed population is assumed to be that portion of Midwest City adjacent to Soldier Creek. This assumption is based on the fact that only the surface water and air pathways potentially affect that population. The contaminated groundwater plume is predicted to remain within the installation boundary over a time span of at least 50 years with horizontal migration to the southwest away from water supply wells of these urban communities. Therefore, a groundwater pathway during this time period to these urban populations does not exist.

The predicted contamination of Soldier Creek by groundwater of the perched aquifer does, as stated previously, provide an exposure pathway to populations along the stream. Soldier Creek originates to the southeast of the Building 3001 complex and flows approximately 5.6 miles to Crutcho Creek north of Midwest City. Population estimates of the community within

one-half, one, and two miles of the stream, developed through 1980 census data, were 5,300, 10,600, and 21,300, respectively. Individuals living within one-half mile of the stream were assumed to be potential receptors by the inhalation exposure route. Estimates of the population using the stream for contact recreation was 7,500. The population using the stream was assumed to be composed of individuals under 16 years of age. Both these assumptions were made in keeping with the conservative approach to this risk assessment.

Sensitive populations of the area are adolescents using the stream for recreation as well as children living within one-half mile of the stream. Schools, nursing homes, and hospitals of the area would also contain sensitive populations. Fourteen schools, three nursing homes, and two hospitals are located within a two-mile corridor of the stream. Sensitive populations assumed to be at the greatest risk are those within the one-half mile corridor of the stream (two schools and one nursing home). Although sensitive populations were identified, quantification of these specific populations was not attempted due to the transient nature of individuals in nursing homes and hospitals. Instead, all individuals using the stream (and thus exposed by the inhalation and absorption routes) were assumed to be children under 16.

Pathway Analysis Summary

The summary of the pathway analysis is shown in table 7. Complete pathways (those with pathway, route, and exposed population) were identified for only the groundwater pathway as drinking water on Tinker AFB. The present contamination of two water supply wells, and the potential contamination of a third well, coupled with the distribution of that water to the population on Tinker AFB completes the pathway. Surface water and air pathways are not presently complete and pose no immediate threat to populations along Soldier Creek. Predictions of groundwater seepage to the stream will complete these pathways and expose additional populations to the contaminants.

TABLE 7. Matrix of Potential Exposure Pathways

Release/ Transport Medium	Exposure Point	Exposure Route	Number of People	Pathway Complete
Groundwater				
Perched	Shallow wells used for non-consumptive domestic use	Ingestion of irrigated crops	N/A	No
		Inhalation & skin contact from non-consumptive uses	N/A	No
Regional	Workplaces at Tinker AFB	Ingestion of water	22,500	Yes
		Inhalation & skin contact from showers and industrial processes	2,500	Yes
Surface Water	At and below seepage area to Soldier Creek	Ingestion of aquatic organisms	7,500*	No
		Dermal contact	5,300*	No
Air	At and below seepage area to Soldier Creek	Inhalation/ Volatilization from surface water	5,300*	No

* Estimated from 1980 census data.

ESTIMATION OF EXPOSURE CONCENTRATIONS

Exposure concentrations from the Building 3001 site represent both subchronic and chronic exposures to the potential receptors identified in the pathway analysis. Subchronic exposures presently exist from the known contamination of two water supply wells (primarily well 16) on Tinker AFB. The concentrations shown in table 8 represent those reported in the remedial investigation report. The remedial investigation reported

contamination of well 15 and 16 as resulting from migration from overlying aquifer layers through well casings. Contamination of well 15 was only in trace amounts with greater concentrations observed in well 16. As a result of only trace contamination of well 15, the concentration values of well 16 were used as estimates of the present (subchronic) exposure from water supply wells. The reported value was used as the best estimate of subchronic exposure concentrations. The conservative estimate was based on the reported value with a 100% increase as a safety factor. Analysis of short-term exposures used these values as representative and conservative concentrations. Subchronic conditions do not presently exist in the surface water and air pathways as a result of the uncontrolled release of contaminants from the Building 3001 complex. Existing contamination of Soldier Creek, if any, was not included in the scope of this endangerment assessment.

Long-term exposures identified in the pathway analysis (table 6) exist for all exposure pathways. Representative concentrations of indicator chemicals were estimated for the pathways using methods described in the following paragraphs.

Long-term exposure concentrations at the potential exposure points (water supply wells and Soldier Creek) were developed from the modeled contaminants (TCE and chromium) in the remedial investigation report (USACE, 1987). Concentrations in the water supply wells were estimated from the cumulative effects of the potential contaminant flow pathways. The first pathway results from the horizontal spread of the contaminated groundwater in the perched and upper regional aquifer zones to the water supply well locations, then vertical flow of the contaminants down the well shafts. The concentrations in the perched and upper regional aquifer zones were predicted from the groundwater model. The portions of the contaminant reaching the well by travelling down the shaft were predicted from relationships in wells where vertical migration had previously occurred. These predictions were made of 10, 50 and 70 years in the future. The second pathway results from vertical migration of the contaminated groundwater in the perched and upper regional zones to the lower producing zone, then flowing into the water supply wells as a result

of pumping effects. Concentrations for this pathway were estimated by using the Vertical-Horizontal Spread model (EPA, 1985) and added to the predicted concentrations from the first pathway. Using the two-dimensional groundwater model of the remedial investigation, concentrations were modeled for TCE and chromium in the perched aquifer at Soldier Creek and in the water supply wells of the regional aquifer at 10, 50, and 70 years in the future. Estimates of other chemicals were based on the predictions of modeled contaminants applied to the non-modeled indicator chemicals. Other indicator chemical plumes and concentrations were compared to predicted TCE and chromium at the 10-, 50-, and 70-year concentrations. The estimates were made using a ratio developed from comparison to TCE or chromium applied to present concentrations.

Estimates of the predicted concentrations at exposure points are shown in table 8. The estimates are considered best estimates because the contaminants have similar dispersivities and retardance in the groundwater as either modeled contaminant (TCE or chromium). The predictions do not account for biological degradation reducing concentrations as they migrate through the groundwater. The 70-year concentration was considered the maximum or conservative long-term concentration with the median value over the 10-, 50- and 70-year time frame as the representative or best estimate value. An arithmetic mean of the best estimate values of the three water supply wells was used as the representative exposure concentration for the Tinker AFB water supply. Those concentrations are worst case for drinking water (in keeping with the conservative approach to this risk assessment), because the water of the contaminated wells is blended with water from additional wells prior to distribution to the base population. Predicted concentrations at Soldier Creek are of groundwater entering the creek and do not account for dilution by creek waters. Therefore, long-term concentrations predicted for Soldier Creek are assumed to be worst case. These assumed worst case concentrations were used in evaluating human intakes at the exposure points for the ingestion route, in keeping with the conservative approach.

TABLE 8. Present and Predicted Exposure Concentrations of Indicator Chemicals at Soldier Creek and Tinker AFB Water Supply Wells.

	Soldier Creek				Water Supply Wells											
					No. 15				No. 16				No. 17			
			Future			Future				Future				Future		
Contaminant	Present* (ug/l)	10 Year	50-yr (ug/l)	70 Year	Present (ug/l)	10 Year	50-yr (ug/l)	70 Year	Present (ug/l)	10 Year	50-yr (ug/l)	70 Year	Present (ug/l)	10 Year	50-yr (ug/l)	70 Year
Trichloroethene	-	<1	500	600	0.7	3	10	15	1.9	5	15	18	<0.5	3	25	30
Tetrachloroethene	-	3	5	8	<0.5	<0.5	<0.5	<0.5	0.7	3	10	13	<0.5	<0.5	<0.5	<0.5
Benzene	-	<5	<5	<5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	2	3
Hexavalent chromium	-	300	7,000	8,000	5	6	8	9	10	12	20	20	5	6	20	18
Lead	-	50	100	120	<10	5	10	10	45	50	50	50	5	6	20	25
Barium	-	1,000	1,500	1,500	580	600	600	600	680	700	700	700	500	800	800	800
Nickel	-	150	200	200	10	12	20	20	25	30	70	70	5	10	50	50

*Pathway incomplete at present time; future contamination predicted.

Exposure from an inhalation route was developed for the surface water pathway. Development of inhalation exposure concentrations were not made directly. Instead they were made by estimating the rate of volatilization of contaminants from the surface water and using that value as the representative exposure concentration. The rate of volatilization was computed from the difference in water concentrations over a one-hour volatilization period by the first order reaction rate (assumed plug flow) as described by Smith, et. al. (1980). Although inhalation is a potential route of exposure from the groundwater pathway during showering and industrial processes by the Tinker AFB population, exposure concentrations could not be quantified because of the numerous unestimable variables involved.

Diffusion constants for the volatile organic indicator chemicals reported were used to develop the reaction rate constant (k). The volatilization concentrations were computed as follows:

$$C_{(x)} = C_o \, e^{-kt}$$

where $C_{(x)}$ is the concentration of indicator chemical remaining in the water.

C_o is the initial water concentration

k is the reaction rate

t is time

The difference between C_o and $C_{(x)}$ adjusted for air concentrations became the estimate of volatilization and the inhalation exposure concentration. Best estimate values for inhalation were based on best estimate values predicted in the surface water and similarity for conservative estimates. The estimated concentrations became input values for an air dispersion model (appendix C, page C-8) as follows:

$$C_{(x)} = \frac{Q}{3.14\ abc}$$

where $C_{(x)}$ is the concentration (in mg/m^3) at 100m or 500m
Q is the release rate (in mg/sec) of indicator chemical
a is the dispersion coefficient (in m) in lateral direction
b is dispersion coefficient (in m) in the vertical direction
c is mean wind speed (in m/sec)

The estimated exposure concentrations of the stream were based on the concentrations of the 100-meter dispersion model. These air values shown in table 9 were assumed worst case (in keeping with the conservative approach to the risk assessment) exposure concentrations for potential receptors throughout the reach of the stream. Estimated exposure concentrations for all pathways at each exposure point are summarized in table 9. The best estimate values were carried through subsequent analyses for characterization of health risks.

Table 9. Contaminant Concentrations at Exposure Points.

Chemical	Release Medium	Exposure Point	Short-Term Concentration Best Estimate	Short-Term Concentration Conservative Estimate	Long-Term Concentration Best Estimate	Long-Term Concentration Conservative Estimate
Benzene	Air	Soldier Creek	N/A	N/A	1.0E-6	3.3E-6
	Groundwater	Tinker wells	<0.5	0.5	0.8	3.0
	Surface water	Soldier Creek	N/A	N/A	<5	<5
Trichloroethene	Air	Soldier Creek	N/A	N/A	4.0E-4	4.7E-4
	Groundwater	Tinker wells	1.9	3.8	16.7	30
	Surface water	SoldierCreek	N/A	N/A	500	600
Tetrachloroethene	Air	Soldier Creek	N/A	N/A	4.1E-6	1.0E-5
	Groundwater	Tinker wells	0.7	1.4	3.5	13
	Surface water	SoldierCreek	N/A	N/A	5	8
Nickel	Air	SoldierCreek	0	0	0	0
	Groundwater	Tinker wells	25	50	47	70
	Surface water	Soldier Creek	N/A	N/A	200	200
Hexavalent Chromium	Air	Soldier Creek	0	0	0	0
	Groundwater	Tinker wells	10	20	16	20
	Surface water	Soldier Creek	N/A	N/A	7000	8000
Lead	Air	Soldier Creek	0	0	0	0
	Groundwater	Tinker wells	45	90	27	50
	Surface water	Soldier Creek	N/A	N/A	100	120
Barium	Air	Soldier Creek	0	0	0	0
	Groundwater	Tinker wells	680	1360	700	800
	Surface water	Soldier Creek	N/A	N/A	1500	1500

Note - Water values in ug/l, air values in mg/cubic meter.

COMPARISON OF EXPOSURE CONCENTRATIONS TO REQUIREMENTS, STANDARDS, AND CRITERIA

The estimated exposure concentrations for each route (inhalation and ingestion of water and fish) were compared to applicable or relevant and appropriate requirements (ARARs). Standards and criteria compared were the maximum contaminant levels (MCL) of the Safe Drinking Water Act (SDWA), drinking water guidance for nickel (50 FR 46936, November 13, 1985), and the State of Oklahoma maximum concentration standards for air toxics (MAAC). Comparisons to applicable requirements are shown by pathway on tables 10 through 12.

Applicable or Relevant and Appropriate Requirements

ARARs were available for the groundwater pathway, ingestion route, for Tinker AFB water wells and the air pathway, inhalation route, of Soldier Creek. Comparisons of exposure concentrations of the water supply were made for all indicator chemicals except PCE. Currently, no MCL exists for PCE and the proposed MCL goal has been set at zero. Comparison of the exposure concentrations to the ARARs (table 10) resulted in most values being less than one, showing that predicted concentrations are not expected to be above the MCL or guidance level for most indicator chemicals. However, short-term concentrations of nickel (0.047 mg/l) are expected to violate the guidance level of 0.015 mg/l as shown by a ratio value of 1.7. Projected long-term concentrations of TCE and nickel are expected to violate the SDWA standard and proposal guidance levels as shown by ratio values of 3.34 and 3.1, respectively; thereby creating potential health risks.

Volatilization from surface water was identified as the only release mechanism for air contamination. Exposure concentrations of the volatile indicator chemicals (benzene, TCE, and PCE) were compared to air toxic standards (MAACs) for Oklahoma (table 11). Predicted exposure concentrations ranged from 10^{-4} to 10^{-6} mg/m^3. Comparison to the MAACs show the projected concentrations to be significantly below the air toxic standards.

TABLE 10. Comparison of Applicable or Relevant and Appropriate Requirements to Estimated Exposure Point Concentrations. (Exposure Point: Tinker AFB Municipal Waterwells - Oral).

Chemical	Applicable or Relevant and Appropriate Requirement	Requirement Concentration (mg/l)	Projected Exposure Point Concentration (mg/l)	Short-term (S) or Long-term (L) Concentration	Concentration: Standard Ratio
Benzene	MCL	0.005	<0.0005	S	<0.1
			0.0008	L	0.2
Trichloroethene	MCL	0.005	0.0019	S	0.38
			0.0167	L	3.34
Tetrachloroethene	--	--	0.0007	S	--
			0.0035	L	
Nickel	PG	0.015	0.025	S	11.7
			0.047	L	3.1
Hexavalent Chromium	MCL	0.05	0.01	S	0.2
			0.016	L	0.32
Lead	MCL	0.05	0.045	S	0.9
			0.0027	L	0.054
Barium	MCL	1.0	0.68	S	0.68
			0.70	L	0.70

Note 1 - Best estimate value used for both short- and long-term concentration.

Note 2 - PG is a proposed guidance level reported in 50 FR 46936, November 13, 1985.

Table 11. Comparison of Applicable or Relevant and Appropriate Requirements to Estimated Exposure Point Concentration. (Exposure Point: Seepage area at Soldier Creek - Inhalation).

Chemical	Applicable or Relevant and Appropriate Requirement	Requirement Concentration (mg/cu m)	Projected Exposure Point Concentration (mg/cu m)	Short-term (S) or Long-term (L) Concentration	Concentration: Standard Ratio
Benzene	MAAC	0.03	N/A	S	N/A
			1.0E-6	L	3.3E-8
Trichloroethene	MAAC	5.40	N/A	S	N/A
			4.0E-4	L	1.5E-6
Tetrachloroethene	MAAC	3.35	N/A	S	N/A
			4.1E-6	L	1.2E-8
Nickel	None - See Note 1				
Hexavalent Chromium	None - See Note 1				
Lead	None - See Note 1				
Barium	None - See Note 1				

Note 1 - Volatilization is the only route of air contamination; no dust or fumes. Metals not volatile at ambient temperature and pressure and thus, no ARAR's.

Note 2 - Best estimate value used for long-term concentration in accordance with worksheet instructions from Risk Assessment Case Study Manual.

Note 3 - MAAC are the maximum ambient air concentration under the state of Oklahoma's Air Toxics Program.

Comparison of Other Criteria, Advisories, and Guidance Concentrations

Indicator chemicals for which ARARs are not available were compared to other criteria or health advisors. Exposure concentrations of the groundwater predicted at the water supply wells of Tinker AFB were compared to Drinking Water Health Advisories (table 12). Drinking Water Health Advisories (DWHA) were taken from the SPHEM. Comparison of PCE for which no ARAR currently exists to the DWHA showed that the predicted PCE concentration was below the lifetime exposure concentration of a 70-kg adult. Other indicator chemicals showed similar comparative results to DWHA's.

Air concentrations and fish ingestion values projected from the surface water pathway were not compared to criteria. ARAR's were available for volatile contaminants with no other criteria available for comparison. Concentrations of contaminants ingested through consumption of fish tissue were developed and compared to acceptable oral intake values in the estimate of human intakes section of the assessment.

Table 12. Comparison of Other Criteria, Advisories, and Guidance to Estimated Exposure Point Concentration. (Exposure Point: Tinker AFB Municipal Waterwells - Oral).

Chemical	Applicable or Relevant and Appropriate Requirement Available	Other Criterion Being Considered	Value of Criterion (mg/l)	Projected Exposure Point Concentration (mg/l)	Short-term (S) or Long-term (L) Concentration	Concentration: Standard Ratio
Benzene	Y	None				
Trichloroethene	Y	None				
Tetrachloroethene	N	DWHA (Note 1)	6.8	0.0007 0.0035	S (Note 3) L	0.001 0.0005
Nickel	Y	DWHA	0.350	0.025 0.047	S L	0.0025 0.0047
Hexavalent Chromium	Y	DWHA	0.17	0.01 0.016	S L	0.06 0.09
Lead	Y	DWHA	0.01 (Note 2)	0.045 0.027	S L	4.5 2.7
Barium	Y	DWHA	1.8	0.68 0.70	S L	0.38 0.39

Note 1 - DWHA criterion are for longer-term or lifetime exposure of a 70-kg adult. This means the short term values are conservative.

Note 2 - Value obtained by extrapolating 20 ug/day to 2 liter/day average adult water intake.

Note 3 - Short-term values shown for information only. EPA has advised not to use short-term estimates for this RA.

ESTIMATION OF HUMAN INTAKE

Human intakes of indicator chemicals were calculated for each pathway, exposure route, and exposure point using methods prescribed by the SPHEM. Subchronic and chronic intakes were developed to determine immediate and long-term health risks, respectively. Chronic exposures were based on standard intakes of contaminated environmental media (water, air, and soils) over a 70-year exposure period. Standard human intake coefficients (appendix D), as provided in the SPHEM, were assumed in intake calculations. Pathways contributing to total exposure are shown in table 13.

TABLE 13. Pathways Contributing to Total Exposure

Exposure Point	Exposure Pathways Contributing to Total Exposure	Comments
1. Soldier Creek at and below seepage area.	Air Inhalation	Long-Term only
	Fish Ingestion	Adult and long-term only.
	Dermal Absorption	Not quantified
		Long-term only
2. Residents/workers at Tinker AFB	Ground-water ingestion	Short- and long-term
	Dermal absorption	Not quantified
	Air Inhalation	Not quantified

Note - Factors which were not quantified are known to be minor exposure pathways and are not likely to be quantified in any future studies.

SUBCHRONIC INTAKES

Subchronic exposures were identified for only one pathway, groundwater. Present contamination of other potential pathways from the migration of contaminated groundwater was not reported; therefore, subchronic intakes of these pathways were not developed. As stated previously, present contamination of the surface water was beyond the scope of this health assessment. The present contamination levels of Tinker AFB water supply wells (table 9) along with a standard intake coefficient (2 liters/day for 70-kg adult) provided subchronic intakes.

Subchronic intakes expressed in mg/kg/day are shown in table 14. The total oral subchronic intakes (SDI) ranged from 1.9×10^{-2} for barium to 7.3×10^{-6} for benzene.

TABLE 14. Total Subchronic Daily Intake (SDI) Calculation. (Total Exposure Point: Tinker AFB Municipal Waterwells. Number of People: 22,500)

Chemical	Ground-Water SDI	Surface Water SDI	Fish Ingestion SDI	Total Oral SDI	Total Air SDI
Benzene	7.3E-6	0	0	7.3E-6	0
Trichloroethene	5.5E-5	0	0	5.5E-5	0
Tetrachloroethene	2.0E-5	0	0	2.0E-5	0
Nickel	7.3E-4	0	0	7.3E-4	0
Hex Chromium	2.9E-4	0	0	2.9E-4	0
Lead	1.3E-3	0	0	1.3E-3	0
Barium	1.9E-2	0	0	1.9E-2	0

Note 1 - Adult exposure values only calculated.

Note 2 - Exposure periods differ between 2,500 residents of installation and 20,000 workers. Longer period for residents applied to both workers and residents, which increases conservative nature of estimate.

Note 3 - All values in mg/kg/day.

CHRONIC INTAKES

Chronic intakes were developed for all pathways at the exposure points of Tinker AFB water supply wells and Soldier Creek. Chronic intakes of groundwater as drinking water for the Tinker AFB population were estimated from the predicted best estimate concentration (table 9) and the standard human intake coefficient for drinking water. Chronic daily intakes expressed as mg/kg/day doses of contaminants are shown in

table 15. Chronic intake values ranged from 10^{-2} to 10^{-5} with benzene ($2.3x10^{-5}$) and barium ($2.0x10^{-2}$) providing the least and greatest contaminant dose, respectively.

TABLE 15. Total Chronic Daily Intake (CDI) Calculation. (Total Exposure Point: Tinker AFB Municipal Waterwells. Number of People: 22,500).

Chemical	Ground-Water CDI	Surface Water CDI	Fish Ingestion CDI	Total Oral CDI	Total Air CDI
Benzene	2.3E-5	0	0	2.3E-5	0
Trichloroethene	4.8E-4	0	0	4.8E-4	0
Tetrachloroethene	1.0E-4	0	0	1.0E-4	0
Nickel	1.4E-3	0	0	1.4E-3	0
Hex Chromium	5.0E-4	0	0	5.0E-4	0
Lead	7.8E-4	0	0	7.8E-4	0
Barium	2.0E-2	0	0	2.0E-2	0

Note 1 - Adult exposure only calculated.

Note 2 - Exposure periods differ between 2,500 residents of installation and 20,000 workers. Longer period for residents applied to both workers and residents, which increases conservative nature of estimate.

Note 3 - All values in mg/kg/day

Note 4 - Dermal and inhalation exposure through showers, dishwashing, etc. not quantified.

The estimated chronic intakes are assumed worst case at Tinker AFB since military residents of the installation are exposed for only a small portion of the assumed exposure period. Exposure of the workforce is also assumed worst case since exposure is only during the work period (40-hour work week) over an exposure period of less than the assumed 70-year exposure. These assumptions are based on the conservative approach used in this risk assessment.

Chronic intakes of indicator chemicals through the surface water and air pathways of Soldier Creek include estimates of air intake through inhalation and surface water through fish ingestion by adults. Although major recreational users of the stream are assumed to be primarily the population under 16 years of age (approximately 7,500 individuals), intakes were computed for adults, because standard intake coefficients are not available for fish ingestion by children. Calculation of chronic intakes for adults at these pathways may lead to an underestimation of risk to children, but may also overestimate risk by applying a lifetime intake factor to a less-than-lifetime period (childhood). Chronic intake estimates expressed in mg/kg/day at Soldier Creek are shown in table 16.

Fish ingestion identified as the only contributor to oral ingestion intake at Soldier Creek was computed using the bioconcentration factor (BCF), the concentration of the chemical in the water (best estimate, long-term), and the standard intake coefficient. The calculation of fish ingestion is as follows:

$$C(x) = BCF \times Co \times constant$$

where C(x) = the intake of an indicator chemical in mg/kg/day
BCF = the bioconcentration factor of the chemical
Co = the concentration of chemical in surface water (mg/l)
Constant = 0.00009 kg fish/kg/day; developed from the intake coefficient divided by a 70-kg adult.

Bioconcentration factors were reported from the SPHEM (appendix E) and assume no differential concentration by different fish species for different contaminants. For the purpose of this assessment, contamination of fish tissue was assumed consistent throughout the stream and did not account for decreasing concentrations of contaminants in the water column or sediments downstream of the source of groundwater infiltration. The concentrations are, therefore, assumed worst case for consumption of fish. These assumptions maintain the conservative nature of the risk assessment. Chronic intake estimates as shown in table 16 range from 1.0×10^{-2} for chromium to 1.0×10^{-6} for benzene.

TABLE 16. Total Chronic Daily Intake (CDI) Calculation. (Total Exposure Point: Soldier Creek at and below seepage area. Number of People: 7,500).

Chemical	Ground-Water CDI	Surface Water CDI	Fish Ingestion CDI	Total Oral CDI	Total Air CDI
Benzene	0	0	1.0E-6	1.0E-6	2.9E-7
Trichloroethene	0	0	5.0E-4	5.0E-4	1.2E-4
Tetrachloroethene	0	0	1.4E-5	1.4E-5	1.2E-6
Nickel	0	0	8.7E-4	8.7E-4	0
Hex Chromium	0	0	1.0E-2	1.0E-2	0
Lead	0	0	4.6E-4	4.6E-4	0
Barium	0	0	0	0	0

Note 1 - All values in mg/kg/day.

Note 2 - All assumptions from SPHEM; no consumption of fish by children, adult intake of freshwater fish = 6.5 g/day, and adult body weight = 70 kg.

Note 3 - Ingestion of surface water was not considered since it is not a treated water supply source. Incidental ingestion was considered a minor component of ingestion and not quantified.

Air intakes of indicator chemicals partitioning from the surface water to the ambient air were calculated from estimated air concentration (table 9) multiplied by the standard intake coefficient divided by 70-kg (weight of average adult). Chronic inhalation values expressed in mg/kg/day are reported in table 16. The chronic intake dose for the volatile indicators ranged from 10^{-4} to 10^{-7} (TCE 1.2×10^{-4}, PCE 1.2×10^{-6}, and benzene 2.9×10^{-7}). Inhalation intakes, like other exposure routes, are considered worst case. Estimated intakes do not account for dispersion and dilution beyond 100 meters, yet potential intakes were assumed constant throughout the stream reach. This assumption was made to maintain the conservative approach to the risk assessment.

CHARACTERIZATION OF POTENTIAL HEALTH RISKS

Characterization of health risks of contaminants through the health assessment process are assumed to be additive, as recommended in the SPHEM. Contaminants with exposure concentrations compared to environmental standards or public health criteria were evaluated for additive risks. Comparisons of projected intakes of indicator chemicals and reference levels for non-carcinogens, and between calculated risks and target risks for potential carcinogens, provide the final estimate of health risks from contaminants released from the Building 3001 site. Subchronic and chronic risks were developed for each exposure pathway and exposure point. Specific health risks computed for each route of exposure are combined to determine the total risk posed by the site.

NON-CARCINOGENIC HEALTH RISKS

Non-carcinogenic risks are developed through the hazard index as described in the SPHEM. The hazard index was calculated from the summation of the ratio of a projected intake to a reference dose for each indicator chemical. Additive effects, as shown by a hazard index greater than unity, may indicate a potential health risk at a specific exposure point. Reference doses for non-carcinogenic effects were the acceptable oral intake values for subchronic and chronic exposures reported in the SPHEM.

Subchronic hazards were calculated for the oral ingestion exposure route of groundwater at Tinker AFB (table 17). Subchronic acceptable intakes were reported for nickel and chromium. The reported hazard index based on the ratios of only those two indicator chemicals was 8.8×10^{-2}. The value indicates non-carcinogenic subchronic health effects do not exist. However, the lack of subchronic values for comparison to predicted intakes does not allow full estimation of health risks. Therefore, subchronic effects are probably an underestimation of risk.

TABLE 17. Calculation of Subchronic Hazard Index. (Total Exposure Point: Tinker AFB Municipal Waterwells).

Chemical	Inhalation			Oral		
	SDI	AIS	SDI:AIS	SDI	AIS	SDI:AIS
Benzene	N/A	N/A	N/A	7.3E-6	-	-
Trichloroethene	N/A	N/A	N/A	5.5E-5	-	-
Tetrachloroethene	N/A	N/A	N/A	2.0E-5	-	-
Nickel	N/A	N/A	N/A	7.3E-4	2.0E-2	3.6E-2
Lead	N/A	N/A	N/A	2.9E-4	-	-
Hex Chromium	N/A	N/A	N/A	1.3E-3	2.5E-2	5.2E-2
Barium	N/A	N/A	N/A	2.0E-2	-	-

Sum of Inhalation SDI:AIS ratios - N/A
Sum of Oral SDI:AIS ratios - 8.8E-2
Sum Total of all ratios - 8.8E-2

Note - All values in mg/kg/day

Potential chronic non-carcinogenic hazards from the drinking water supply of Tinker AFB are reported in table 18. Chronic acceptable intake (AIC) values were not available for benzene and TCE; therefore, the hazard index value was based on other indicator chemicals. The total hazard index value by the oral exposure route was 1.18 with lead and barium having the greatest effect. Inhalation was an exposure route not quantified during the assessment. Inhalation exposure intakes, assumed low because the majority of contamination is subsurface, would slightly increase the total hazard index. Because the total chronic hazard index for the water supply is greater than unity, it is assumed that some non-carcinogenic effects might result from long-term exposure to the Tinker AFB water supply. The evaluation of potential chronic effects are based on the assumption that predicted contaminant concentrations of the water supply wells are not diluted in the base water distribution system or reductions in concentrations as a result of base water treatment methods. In addition, all barium was assumed to be in the most toxic, soluble form, and concentrations of lead and barium do not decrease over

the long-term time frame (70 years). Therefore, the hazard index value is considered worst case for this pathway, in keeping with the conservative approach of the risk assessment.

TABLE 18. Calculation of Chronic Hazard Index. (Total Exposure Point: Tinker AFB Municipal Waterwells).

	Inhalation			Oral		
Chemical	CDI	AIC	CDI:AIC	CDI	AIC	CDI:AIC
Benzene	See Note 1			2.3E-5	-	-
Trichloroethene	See Note 1			4.8-E-5	-	-
Tetrachloroethene	See Note 1			1.0E-4	2.0E-2	5.0E-4
Nickel	See Note 2			1.4E-3	1.0E-2	0.14
Lead	See Note 2			7.8E-4	1.4E-3	0.55
Hex Chromium	See Note 2			5.0E-4	5.0E-3	0.10
Barium	See Note 2			2.0E-2	5.1E-2	0.39

Sum of Inhalation CDI:AIC ratios = N/A
Sum of Oral CDI:AIC ratios = 1.18
Sum Total of all ratios = 1.18

Note 1 - Inhalation exposure through showers, etc. not quantified for 2,500 base residents. No inhalation exposure projected for 20,000 base workers who are not residents.

Note 2 - No inhalation exposure for metals.

Chronic non-carcinogenic hazards of the inhalation and fish ingestion routes were combined in table 19 for a hazard index of exposures at Soldier Creek. The hazard index for the inhalation route was not quantified because AIC values were not available for volatile indicator chemicals. The hazard index of exposures to Soldier Creek following contamination by perched aquifer infiltration was determined by the oral ingestion route. The AIC values used as reference doses assumed (following the conservative risk assessment approach) total acceptable intake by any media ingested. The hazard index for fish consumption was estimated at 2.12 indicating potential health risks. Chromium essentially

accounted for all the risk with a ratio value of 2.0. Other indicator chemicals accounted for extremely small portions (10^{-2} to 10^{-4}) of the non-carcinogenic risk.

TABLE 19. Calculation of Chronic Hazard Index. (Total Exposure Point: Soldier Creek at and below seepage point).

	Inhalation			Oral		
Chemical	CDI	AIC	CDI:AIC	CDI	AIC	CDI:AIC
Benzene	2.9E-7	-	-	1.0E-5	-	-
Trichloroethene	1.2E-4	-	-	5.0E-4	-	-
Tetrachloroethene	1.2E-6	2.0E-2	6.0E-5	1.4E-5	2.0E.2	7.0E-4
Nickel	0	1.0E-2	-	8.7E-4	1.0E-2	8.7E-2
Lead	0	5.0E-3	-	4.6E-4	1.4E-2	3.3E-2
Hex Chromium	0	1.4E-3	-	1.03-2	5.0E-3	2.0
Barium	0	5.1E-2	-	N/A	5.1E-3	-

Sum of Inhalation CDI:AIC ratios = N/A
Sum of Oral CDI:AIC ratios = 2.12
Sum Total of all ratios = 2.12

Note 1 - All values in mg/kg/day

POTENTIAL CARCINOGENIC HEALTH RISKS

Potential carcinogenic risks were developed using the chronic daily intake multiplied by the calculated or target carcinogenic potency factors for each indicator chemical. Carcinogenic potency factors were those reported in the SPHEM. Route specific risks for each exposure point (Tinker AFB water supply and Soldier Creek) were calculated. Total chemical risks were the summation of the route specific risk for each exposure point.

The carcinogenic indicator chemicals representing health risks in the assessment were benzene, TCE, and PCE. No inorganic indicator chemical selected as representative of significant health risk is an oral

carcinogen. Nickel and chromium produce carcinogenic effects only through the inhalation of particulates (appendix B). Inhalation of contaminated dusts or particulates was eliminated as an exposure route with reported contamination of only subsurface soils and waters.

Carcinogenic risks from contaminant ingestion at Tinker AFB reflect only the quantified risks of the oral route (table 20). The total long-term chemical risks for benzene, TCE, and PCE were 1.2×10^{-6}, 5.3×10^{-6}, and 5.1×10^{-6}, respectively. The total upper bound risk of additional cancers in the exposed population at Tinker AFB was 1.2×10^{-5} (1 cancer/83,000 people). Reported acceptable risks fall within the range of 1.0×10^{-5} to 1.0×10^{-7}. The upper bound risk at Tinker AFB from groundwater as a drinking water source lies just outside this acceptable range. The risk value represents an upper bound or conservative estimate of risk as developed throughout the assessment. With an installation population of 22,500, an observed increase in carcinogenic effects from the Building 3001 site would be unlikely.

Carcinogenic effects resulting from contaminant exposures at Soldier Creek are shown in table 21. Route specific risks for each carcinogen range from 10^{-6} to 10^{-8} for the oral route and from 10^{-7} to 10^{-9} for the inhalation route. Total chemical risks for benzene, TCE, and PCE are 6.0×10^{-8}, 6.1×10^{-6}, and 7.1×10^{-7}, respectively. The total upper bound cancer risk is 6.9×10^{-6}, which lies within the accepted risk range. The carcinogenic risk from exposures to air and waters of Soldier Creek is considered low, based on the characterization of risk.

SUMMARY OF HEALTH RISKS

The risk characterization of the site indicates a potential for carcinogenic and non-carcinogenic health effects as a result of no remedial action on the Building 3001 site. Estimates of risks are assumed to be conservative based on the assumptions described in this document and the fact that reference doses and target risks have been developed to protect public health. Specific health risks were indicated for both carcinogenic and non-carcinogenic effects from long-term consumption of

TABLE 20. Calculation of Risk From Potential Carcinogens. (Total Exposure Point: Tinker AFB Municipal Wells).

Chemical	Exposure Route	CDI (mg/kg/day)	x Carcinogenic Potency Factor (mg/kg/day)-1	= Route Specific Risk	Total Chemical-Specific Risk
Benzene	Oral	2.3E-5	5.2E-2	1.2E-6	1.2E-6
	Inhalation	0	2.6E-2	0	
Trichloroethene	Oral	4.8E-4	1.1E-2	5.3E-6	5.3E-6
	Inhalation	0	4.6E-3	0	
Tetrachloroethene	Oral	1.0E-4	5.1E-2	5.1E-6	5.1E-6
	Inhalation	0	1.7E-3	0	
Nickel	Oral	1.4E-3	None	0	0
	Inhalation	0	N/A	0	
Lead	Oral	7.8E-4	None	0	0
	Inhalation	0	N/A	0	
Hex Chromium	Oral	5.0E-4	None	0	0
	Inhalation	0	N/A	0	
Barium	Oral	2.0E-2	None	0	0
	Inhalation	0	N/A	0	

TOTAL UPPER BOUND RISK = 1.2E-5

Table 21. Calculation of Risk From Potential Carcinogens. (Total Exposure Point: Soldier Creek at and below seepage point).

Chemical	Exposure Route	CDI (mg/kg/day)	x	Carcinogenic Potency Factor (mg/kg/day)-1	=	Route Specific Risk	Total Chemical-Specific Risk
Benzene	Oral	1.0E-6		5.2E-2		5.2E-8	6.0E-8
	Inhalation	2.9E-7		2.6E-2		8.0E-9	
Trichloroethene	Oral	5.0E-4		1.1E-2		5.5E-6	6.1E-6
	Inhalation	1.2E-4		4.6E-3		5.5E-7	
Tetrachloroethene	Oral	1.4E-5		5.1E-2		7.1E-7	7.1E-7
	Inhalation	1.2E-6		1.7E-3		2.0E-9	
Nickel	Oral	8.7E-4		None		0	0
	Inhalation	0		N/A		0	
Lead	Oral	4.6E-4		None		0	0
	Inhalation	0		N/A		0	
Hex Chromium	Oral	1.0E-2		None		0	0
	Inhalation	0		N/A		0	
Barium	Oral	0		None		0	0
	Inhalation	0		N/A		0	

TOTAL UPPER BOUND RISK = 6.9E-6

Tinker AFB drinking water. Non-carcinogenic risks were based on the additive effects of indicator chemicals rather than a specific contaminant. No present short-term hazards from consumption of groundwater were identified during the risk characterization. The potential for carcinogenic effects from long-term consumption of drinking water at Tinker AFB was indicated by the upper bound risk of 1.2×10^{-5}.

Health risks were also identified from the long-term consumption of fish taken from Soldier Creek. Non-carcinogenic effects were indicated by a high hazard index value. Most of the additive effect was based on the intake of bioconcentrated chromium. Carcinogenic effects were not identified from contaminant releases to Soldier Creek. Route-specific risks for inhalation and ingestion were low with an upper-bound risk within the range of accepted risk.

The health impacts discussed have been based on concentrations detected in the groundwater regardless of the source. As discussed previously, the present and predicted concentrations of well 16 (table 8) result from migration of contaminants released from Building 3001 and an unknown source. The concentrations of well 16 attributed only to releases from Building 3001, as determined through additional modeling, were lower then those combined with the unknown source for most organic constituents and for nickel (appendix G, Table G-1). The variations in predicted long-term concentrations based on releases from Building 3001 as the sole source of contamination of the groundwater results in slight variations in the characterization of non-carcinogenic and carcinogenic health effects. These variations are shown in alternative health assessment worksheets in appendix G.

The exposure concentrations attributed to Building 3001 resulted in variations to only long-term exposure assessments through the water supply route of exposure. The chronic non-carcinogenic risks of the alternative assessment (appendix G, table G-28) showed an equivalent potential for health effects to contamination from all sources with a hazard index value of 1.17. The HI indicates that health effects may result from long-term ingestion of Tinker AFB drinking water. Carcinogenic risks from exposure

to contaminants in installation wells were lower than the assessment of all contamination sources (Building 3001 and the unknown source). The risk characterization of carcinogens in the alternative assessment (appendix G, table G-30) was within acceptable values ($5.9x10^{-6}$). The alternative assessment indicates that carcinogenic health effects would not be expected from contaminant releases from only Building 3001 to drinking water supplies.

UNCERTAINTIES IN THE CHARACTERIZATION OF HEALTH RISKS

During the development of the characterization of public health risks of contaminant releases from the Building 3001 site, uncertainties were identified that may lead the endangerment assessment to over or underestimate health risks. Many of the uncertainties are inherent to the assessment methodology or to chemical characterization of a site. Other uncertainties, such as only one round of available sample data, may be resolved as better information becomes available. Whether or not this information is used to update this risk assessment will be dependent on the changes to existing information and funding. The uncertainties identified in this assessment are discussed in the following.

Uncertainties That May Underestimate Health Risks

The quantification of risk discussed in this assessment has been based on the assumption that the indicator chemicals selected are representative of the greatest risk from all contaminants of the site. An incorrect assumption would lead to underestimation of risk.

The characterization of the groundwater underlying the Building 3001 complex has been based on a single set of samples for many parameters. Chemical contaminants that significantly add to the risk may not have been identified through the sampling design or parameters chosen for analyses.

Modeled data or the assessment does not account for the potential for biotransformation to result in compounds of greater health risk.

No quantification of inhalation or dermal absorption from showering and industrial processes on Tinker AFB or dermal absorption from recreating in Soldier Creek may underestimate risks.

The assumption that Soldier Creek is the principle exposure area coupled with the inability to quantify downstream concentrations may underestimate the population at risk.

The prediction that the contaminated groundwater plume will continue to move away from on and off base water well fields may underestimate risk if incorrect.

The effects of wells 13 and 14 were not evaluated because they are currently uncontaminated and thus do not represent exposure points. Although future predicted plume movements encompass these wells, predicted concentrations would be low. Inclusion of these low concentrations in calculation of the average would thus lower the representative concentrations, thereby erroneously decreasing risk.

The inability to compare estimated intakes of chemicals without AICs provides an underestimate of additive risk.

Quantification of risk from exposures at Soldier Creek are for adults and may underestimate risks for children.

Risks may be underestimated for municipal water users on TAFB if contaminated waters from a single well of higher concentration (ie. well 16) is pumped directly to a building for usage rather than a from a series of wells blended as assumed in its use of representative concentration.

Available information was not sufficient to assess synergistic effects (the combined effects of two of more chemicals exceed the additive effects of the individual chemicals). Health risks would be increased if synergistic effects are occurring.

Uncertainties That May Overestimate Health Risks

Chemical data uncertainties that may overestimate risk include the use of total metal concentrations in the assessment, the assumption that all chromium was hexavalent, and the assumption that barium was of more toxic forms.

The assumption that bioconcentration by fish is constant throughout the stream may overestimate actual ingestion intakes by this route of exposure.

Modeled data does not account for the potential reduction in concentrations due to biodegradation, or biotransformation to less toxic compounds.

The general methodology used by EPA for risk assessment is conservative and numerous factors provided by the SPHEM contain safety margins of 100 to 1000.

Dilution in Soldier Creek is assumed to be negligible, which is not true during periods of high flow.

Durations of exposure to all pathways would generally be expected to be shorter than estimates used in the risk assessment.

Uncertainties That May Over or Underestimate Health Risks

The assumptions that are inherent with the development of modeled data provide the potential for either over or under estimation of the exposure concentrations and health risks. In addition, the estimation of concentrations of non-modeled indicator chemicals based on the comparison to modeled parameters of similar plumes and dispersivities may allow over or under estimation of those chemicals.

Biochemical interaction of lead may be under or overestimated because of the deletion of cadmium, copper, and zinc in the evaluation of intakes.

The inability to predict biotransformation products of lesser or greater toxicity may under or overestimate the risk characterization and impact on public health.

Degradation of chemicals will increase the content of degradation products (which may have toxicity) while the amount of the degraded compound will decrease. No information is available to allow prediction of these changes and this uncertainty may increase or decrease the actual health risk.

The assumption that well 17 is contaminated although it has not been sampled may under or over estimate the concentrations of indicator chemicals.

GLOSSARY LIST OF ACRONYMS

Acronym	Meaning
ADI	Acceptable Daily Intake
AFB	Air Force Base
AIC	Acceptable Intake for Chronic Exposures
AIS	Acceptable Intake for Subchronic Exposures
ARAR	Applicable or Relevant and Appropriate Requirement
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CDI	Chronic Daily Intake
DWHA	Drinking Water Health Advisories
IS	Indicator Score
K_{oc}	Organic-carbon partition coefficient
K_{ow}	Octanol-water partition coefficient
MAAC	Maximum Ambient Air Concentrations
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
NAAQS	National Ambient Air Quality Standards
NC	Noncarcinogen
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
PC	Potential Carcinogen
PCE	Tetrachloroethene
RI	Remedial Investigation
SDI	Subchronic Daily Intake
SDWA	Safe Drinking Water Act
SEAM	Superfund Exposure Assessment Manual
SPHEM	Superfund Public Health Evaluation Manual
TCE	Trichloroethene
USACE	US Army Corps of Engineers
USEPA	US Environmental Protection Agency
WQC	Water Quality Criteria

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APPENDIX A

WEIGHT OF EVIDENCE CATEGORY FOR CARCINOGENS AND SEVERITY RATING CONSTANTS FOR NON-CARCINOGENS

TABLE A-1. EPA Weight-of-Evidence Categories for Potential Carcinogens*

EPA Category	Description of Group	Description of Evidence
Group A	Human Carcinogen	Sufficient evidence from epidemiologic studies to support a causal association between exposure and cancer
Group B1	Probable Human Carcinogen	Limited evidence of carcinogenicity in humans from epidemiologic studies
Group B2	Probable Human Carcinogen	Sufficient evidence of carcinogenicity in animals, inadequate evidence of carcinogenicity in humans
Group C	Possible Human Carcinogen	Limited evidence of carcinogenicity in animals
Group D	Not classified	Inadequate evidence of carcinogenicity in animals
Group E	No Evidence of Carcinogenicity in Humans	No evidence for carcinogenicity in at least two adequate animal tests or in both epidemiologic and animal studies

* From Superfund Public Health Evaluation Manual

TABLE A-2. Rating Constants (RVe) for Non-Carcinogens*

Effect	Severity Rating (RVe)
Enzyme induction or other biochemical change with no pathologic changes and no change in organ weights.	1
Enzyme induction and subcellular proliferation or other changes in organelles but no other apparent effects.	2
Hyperplasia, hypertrophy or atrophy, but no change in organ weights.	3
Hyperplasia, hypertrophy or atrophy with changes in organ weights.	4
Reversible cellular changes: cloudy swelling, hydropic change, or fatty changes.	5
Necrosis, or metaplasia with no apparent decrement of organ function. Any neuropathy without apparent behavioral, sensory, or physiologic changes.	6
Necrosis, atrophy, hypertrophy, or metaplasia with a detectable decrement of organ functions. Any neuropathy with a measurable change in behavioral, sensory, or physiologic activity.	7
Necrosis, atrophy, hypertrophy, or metaplasia with definitive organ dysfunction. Any neuropathy with gross changes in behavior, sensory, or motor performance. Any decrease in reproductive capacity, any evidence of fetotoxicity.	8
Pronounced pathologic changes with severe organ dysfunction. Any neuropathy with loss of behavioral or motor control or loss of sensory ability. Reproductive dysfunction. Any teratogenic effect with maternal toxicity.	9
Death or pronounced life-shortening. Any teratogenic effect without signs of maternal toxicity.	10

* From Superfund Public Health Evaluation Manual

APPENDIX B

CHEMICAL DATA SHEETS

CHEMICAL DATA SHEET

Chemical Name: Barium

CAS # 7440-39-3

Molecular Weight: 137.34

Normal Physical State: Solid

Specific Gravity: 3.51 g/cm^3 @ 20° C

Solubility (water): Decomposes, combines with 1) sulfate present in natural waters to form BaSO4 which has the solubility of 0.222 mg/100 ml at 18° C or 2) carbonate which has the solubility of 2 mg/100 ml at 20° C

Boiling Point: Dependent upon specific salt form

Melting Point: Dependent upon specific salt form

Vapor Pressure: 10 mm Hg at 1049° C

Vapor Density: NA

Flash Point: NA

Autoignition Point: NA

Henry's Law Constant: NA

Organic Carbon Partition Coefficient (Koc): Dependent upon specific form

Octanol-Water Partition Coefficient (Kow): Dependent upon specific form

Fish Bioconcentration Factor: not reported

Summary of Transport and Fate

Particulate barium is likely to be present in the atmosphere from industrial emissions. The main mechanisms for removal of barium compounds in the atmosphere are likely to be wet precipitation and dry deposition after a residence time of several days, depending on the particulate size and chemical nature of the particulate. In soils, the formation of water-insoluble salts and its inability to form soluble complexs with humic and fulvic materials probably limit mobility. Under acidic conditions, some of the water insoluble barium compounds may become soluble and move into groundwater. Aquatic barium is likely to be present primarily as suspended matter or sediments. The presence of sulfate in natural waters generally limits barium to trace amounts (a few ppm) in surface or groundwater. This low solubility of barium sulfate may be made considerably more soluble in the presence of chloride and other anions. The other important solubility limitation is that of barium carbonate. Monitoring programs show that it is rare to find barium in drinking water at

concentrations greater than 1 mg/L. Bioaccumulation is not on important process for barium.

Summary of Health Effects

An oral AIC of 3.6 mg Ba/day has been estimated based on a LOAEL of 100 mg Ba/L in drinking water. This estimate was based primarily on a rat study showing an increase in systolic blood pressure following consumption of water containing 100 mg Ba/L. Data were inadequate for development of an oral AIS for barium. A composite score (CS) of 45 was associated with shortened lifespan in male mice. There are no reports of carcinogenicity, mutagenicity, or teratogenicity associated with exposure to barium or its compounds.

An AIS and AIC for inhalation exposure have been estimated as .098 and 0.01 mg/day, respectively. These 70 kg human estimates are based on a rat study following exposure to 3.62 mg Ba/m^3. Appropriate human data addressing reproductive issues are not available.

The insoluble forms of barium, e.g. barium sulfate, are not toxic by ingestion or inhalation because only minimal amounts are absorbed. Soluble barium compounds are highly toxic in humans by either route. The most important effect of acute barium poisoning is a strong, prolonged stimulant action on muscle (smooth, cardiac, and skeletal) and a transient increase in blood pressure due to vasoconstriction. Doses of barium carbonate (57 mg/kg) and barium chloride (11.4 mg/kg) have been reported to be fatal in humans. The biological half-life for barium is less than 24 hours.

CHEMICAL DATA SHEET

Chemical Name: Benzene

CAS# 71-43-3

Molecular weight: 78.12 g/mole

Normal physical state: Liquid

Specific gravity: 0.879 at 68° F

Solubility (water): 1.750 mg/L at 77° F

Boiling point: 177° F

Melting point: 42° F

Vapor pressure: 75 mm Hg at 68° F; 95.2 mm Hg at 77° F

Vapor density: 2.77

Flash point: 52° F

Autoignition point: 1076° F

Henry's Law Constant: 5.59×10^{-3} $atm\text{-}m^3/mole$

Organic Carbon Partition Coefficient (Koc): 83 ml/g

Octanol-Water Partition Coefficient (log Kow): 2.12

Fish Bioconcentration Factor: 5.2 l/kg

Summary of Transport and Fate

Benzene is a naturally occurring compound in crude oil and natural gas varing in content usually between 0.1 and 3.0 percent by volume. The petrochemical and petroleum refining industries are the producers for 98 percent of the total U.S. production of benzene. Benzene may reach the environment through a variety of routes; however its volatilization is a prime transport process. Under ordinary atmospheric conditions, the low boiling point and high vapor pressure cause rapid evaporation of benzene from liquids containing various quantities of benzene and from contaminated soils and surface waters. In ambient air, rapid photooxidation may occur (the air half-life is estimated to be 6 days). Since evaporation is likely to be the main transport process accounting for the removal of benzene from water (water half-life estimated 1-6 days), the atmospheric photooxidation of benzene is probably the most likely fate process. The half-life of the benzene in aquatic media has been estimated from the reaeration rate ratio of 0.574 and the oxygen reaeration rate of 0.19 to 0.96 per day. By analogy with its probable fate in aquatic media, evaporation is expected to be the predominant loss mechanism from the soil surface. The log Kow value indicates that sorption onto organic material may be significant and is a likely contributory removal mechanism in both surface and ground waters. In addition, the

reasonably high water solubility and reasonably low soil-water distribution coefficient suggests that benzene is expected to leach from soil. The low frequency of occurence (8.5%) of benzene in groundwater samples compared to chloroform (70%) suggests that both biodegradation and volatilzation may account for the primary loss of benzene from the soil before it has the chance to leach appreciall from soil to groundwater. Biodegradation by microorganisms may be enhanced by the presence of other hydrocarbons. The fish bioconcentration factor is low.

Summary of Health Effects

Inhalation of benzene by occupationally exposed workers has resulted in leukemia and diseases of the blood and blood-forming organs. The 1987 final benzene OSHA standard of 1 ppm for a working lifetime of 45 years is calculated to reduce (to approximately 10 per 1000 exposed) but not eliminate deaths as a result of benzene exposure. The carcinoginic effects of benzene are supplemented by a variety of other diseases and various toxic effects in both humans and animals. This includes multiple myeloma, aplastic anemia and various other sometimes reversible blood disorders such as leukopenia and thrombocytopenia. Benzene has also been shown to cause damage to genetic material in both human and animal cells resulting in chromosomal abevrations. Several studies have demonstrated that benzene administered either by oral gavage or by inhalation induces cancer of multiple sites in experimental animals. The human data linking inhalation exposure to benzene with leukemia is strong; however, cancer incidence in humans following oral exposure is not available. EPA has estimated a human carcinogenic potency (q_1^*) for inhaled benzene of 2.59×10^{-2} $(mg/kg/day)^{-1}$ from epidemiological data. Similarily, a human oral carcinogenic potency (q_1^*) of 4.4512×10^{-2} $(mg/kg/day)^{-1}$ was calculated based on one orally administered benzene animal bioassay by using a linearized multistage model.

CHEMICAL DATA SHEET

Chemical Name: Chromium

CAS # 7440-47-3

Molecular Weight: 52 g/mole

Normal Physical State: Solid

Specific Gravity: 7.20 @ 82° F

Solubility (water): As chromium metal, insoluble; salt forms, soluble

Boiling Point: 3992° F

Melting Point: 3434° F

Vapor Pressure: 0

Vapor Density: NA

Antoignition Point: NA

Henry's Law Constant: NA

Organic Carbon Partition Coefficient (Koc): Not reported

Octanol-Water Partition Coefficient (log Kow): Not reported

Fish Bioconcentration Factor: 16 1/kg

Transport and Fate

Chromium is a naturally occuring metal that may exhibit several oxidation states, ranging -2 to +6; these dictate its chemical reactivity and its biological and environmental significance. The most common oxidation states are the trivalent Cr III and hexavalent Cr VI states. Cr VI is a moderately strong oxidizing agent and reacts with reducing materials to form Cr III. Cr III is the most stable and has a strong tendency to form complexes with organic and inorganic ligands; these compounds persist for relatively long periods in solution. In solution, Cr VI is quite soluble and may exist as the hydrochromate, chromate and dichromate species; the proportion of each ion is pH dependent.

Cr III and Cr VI are readily interconvertible in nature depending on environmental conditions such as pH, hardness, and presence of other compounds. Chromium is amphoteric and can exist in water in more than one form. Cr III is usually precipitated as chromium hydroxide, associated with particulate matter, and absorbed into sediments. Cr VI in all forms is soluble, and is quite mobile in the aquatic environment. It may exist as a soluble complex anion and may persist for a long time. In the presence of organic matter, however, Cr VI will exhibit a much shorter lifetime. Soluble forms of Cr accumulate if ambient conditions favors Cr VI; when conditions favor Cr III precipitation and accumulation of Cr in sediment occurs.

In soil, Cr III usually as chromium hydroxide is the predominant form present because the presence of organic materials favor the conversion of Cr VI to Cr III. Cr VI of natural origin is rarely found in soils. Cr VI compounds are not strongly adsorbed by soil components and are mobil in groundwater. Cr III can be adsorbed strongly onto clay particles and organic particulate matter. It can be mobilized if it is complexed with water soluble complexes. Cr can be transported to the atmosphere by way of aerosol formation and through/from soil via runoff. Cr probably exists in ambient air in both the 0, III, and VI form. The Cr (0) and Cr III should not undergo any reaction, whereas Cr VI may eventually react with particulate matter or other pollutants to form Cr III. The exact nature of these reactions is not clearly understood. Removal of Cr compounds from air occur via fallout and precipitation; half-life is dependent on particle size and density.

Health Effects

Cr III and CR VI have greatly differing toxicity characteristics; only the Cr VI species readily crosses cell membranes. The Cr III form is a nutritionally essential element and is much less toxic than Cr VI. Basically Cr III has no established systemic toxicity; when injested does not give rise to local and systemic effects and is poorly absorbed. The chief health problems associated with Cr are related to Cr VI which is irritant and corrosive and may be absorbed by ingestion, through the skin, and by inhalation. Cr VI has been shown to produce liver and kidney damage, internal hemorrhage, respiratory irritation, inflammation and disorders, dermatitis (including contact dermatitis in sensitive individuals) and ulceration of the skin and nasal septum. Cr has been designated as a compound with sufficient evidence for carcinogenicity in humans and animals on the basis of the data for inhaled Cr VI; however, Cr has not been shown to be carcinogenic through ingestion exposure. Cr VI compounds have been shown to cause DNA and chromosomal changes in both animals and humans and certain Cr VI compounds are teratogenic in animals.

CHEMICAL DATA SHEET

Chemical Name: Lead

CAS# 7439-92-1

Atomic Weight: 207.2

Normal physical state: Solid metal

Specific gravity: 11.34

Solubility water: 0.001 -0.01 mg/L, salt form dependent as well as pH.

Boiling point: 3164° F

Melting point: 3164° F

Vapor pressure: 1.77 mm Hg @ 1832° F

Henry's Law Constant: N/A

Organic Carbon Partition Coefficient (Koc): dependent of form

Octanol - Water Partition Coefficient (log Kow): dependent upon form

Fish Bioconcentration Factor: 49 l/g

Summary of Transport and Fate

Lead is ubiquitous in nature and is a characteristic trace constituent in rocks, soil, water, air and biological specimens. Naturally occuring lead is commonly regarded as being geochemically immobile and not readily solubilized during chemical weathering. Lead leached from ore-bearing formations is adsorbed by ferric hydroxide or combines with carbonate or sulfate ions to form insoluble compounds. Movement through soil invariably involves transport in particulate or sorbed forms. Some industrially produced lead compounds are readily soluble in water.

Atmospheric lead is generally in particulate form; their size, shape and solubility determine the dynamics of dispersion, deposition, retention, and absorption. The major forms are complex halides or mixed oxides and sulfates. Atmospheric transport represents the major transport process for lead and its inorganic and organic compounds. Lead particulcates are removed from the atmosphere by dry deposition, either by sedimentation, diffusion or impaction, and to a lesser extent, depending on precipitation, by wet deposition. Dry deposition is the most effective over short distances; wet deposition becomes more important over long distances. Photolysis of lead occurs readily in the atmosphere and is a major factor in determining the form of lead entering the aquatic and terrestrial systems. Sorption appears to exert a dominant effect on the distribution.

In the aquatic environment, lead exists as an insoluble form adsorbed to solid particles and as a dissolved form chelated with water and organic matter. Lead

in solution may become fixed in sediments by precipitation of mineral phases, settling out of organic remains, sorption by organic matter, and inorganic mineral components, e.g. hydrous iron and manganese oxides. Transport is influenced by the speciation of the ion; the divalent cation is most common. Lead appears to be sorbed by clay particles and colloidal fractions in surface waters. Organic and humic and fulvic acids in natural water have a large binding capacity for Pb and form strong complexes with lead. In ground water, lead can exist as simple cations, as complexed ions, and adsorbed on particulate matter.

Sediments represent the primary sink for lead in the aquatic environmental. Partitioning between the aqueous and solid phases is determined by the geological setting, composition of the sediments, pH, temperature, redox potential, availability of ligands, ionic competition, the form of lead, and amount of biological activity. Over most of the normal pH range, lead carbonate and lead sulfate control the solubility in aerobic conditions; lead sulfide and the metal control solubility in anaerobic conditions. The equilibrium solubility of lead with carbonate, sulfate, and sulfide is low.

Soils have a large capacity to bind or immobilize lead so that little is exchangeable; the exchange capacity depends on soil pH and the presence of organic matter and other inorganic compounds. Soils represent the major sink for subaerial pollutant lead; however, most aerially deposited lead is not mobilized down the soil profile by leaching. Because of the low solubilities of secondary mineral lead compounds and the strong binding capacity of soil components for lead, lead has a low geochemical mobility, therefore lead precipitated in top soils will not be significantly leached into the lower horizons. Wind erosion of contaminated soil is a major factor in the environmental distribution of lead.

Lead has been shown to be bioaccumulated by a variety of organisms; bioconcentration factors range from 40 to 1,000. It is not biomagnified through the food chain, although biomethylation by microorganisms can remobilize lead to the environment.

Summary of Health Effects

Chronic exposures to lead, through inhalation and ingestion, have been associated with development of gross neurological, hematopoietic and renal impairments, and reproductive dysfunction; although under conditions of prolonged uncontrolled excessive exposures, the effects usually resemble acute poisoning. Adverse subclinicial changes in the synthesis of heme, the endocrine system, and subtle reproductive and central nervous system impariments have been reported to occur at low levels. It is generally agreed that these subclinical effects are more likely to occur in the child than the mature adult.

Currently, the most sensitive effect is that on heme synthesis, as demonstrated by elevations in the precursors of heme including delta aminolevulinic acid, coproporphyrin, and free erythrocyte protoporphyrin. These effects may occur in association with lower exposure levels than those that produce effects on any other system. Relatively high exposure levels may result in shortened erythrocyte lifespan and anemia.

The central and peripheral nervous system effects of lead have been demonstrated in both human and animal populations, although the data does not clearly eluci-

date a dose-response relationship. Studies have suggested that permanent learning disabilities may occur in children which are clinically undetectable at low levels of exposure. Peripheral neuropathy, behavioral changes, and altered sensitivity to pain as well as encephalopathy and permanent brain damage have also been associated with chronic lead exposure but at relatively high exposure levels. Acute exposures to lead may result in reversible kidney damage, although prolonged exposures may result in development of progressive kidney damage, kidney failure, and possibly hypertension. Other data, both animal and human, are suggestive of effects on the skeletal and immune systems.

There is evidence that inorganic lead salts have been associated with development of renal tumors in rats and mice, lung tumors in hamsters, and brain tumors in rates, however, the epidemiological evidence is equivocal at best and inadequate to determine a dose-response relationship. It is likely that if lead is a human carcinogen, it is a relatively weak one. The data are not sufficient to evaluate the carcinogenicity of metallic lead or organic lead.

There is conclusive evidence in both humans and animals that lead crosses the placenta and accumulates in fetal tissues, especially the brain, and may result in subtle toxic effects not evident at birth. There is little evidence that lead causes overt congential malformations, although it has been associated with an increased hazard of miscarriage or stillbirth. There is also suggestive evidence that lead may cause chromosomal abnormalities and is considered to be a weak environmental mutagen.

Lead and lead compounds are most appropriately classified as Group 3 - possible Human Carcinogens, using the criteria proposed by the EPA Carcinogen Assessment Group. In order to limit inhalation, dietary and dust exposures, the current air standard of 1.5 ug/m^3 has been suggested as a maximum; similarily it has been suggested that water maximum levels be 50 ug/l. Because of uncertainly as to human LOAEL, NOAEL, and subsequent effects at blood lead levels below 30 ug/dl, AIC and AIS levels are not proposed. A composite score of 35 has been suggested.

CHEMICAL DATA SHEET

Chemical Name: Nickel

CAS # 7440-02-2

Molecular Weight: 58.69

Normal Physical State: Solid

Specific Gravity: 8.90

Solubility (water): generally insoluble in alkaline solutions, slightly soluble in acid solutions

Boiling Point: 5252° F

Melting Point: 2651° F

Vapor Pressure: NA

Vapor Density: NA

Henry's Law Constant: NA

Organic Carbon Partition Coefficient (Koc): dependent on form

Octanol-Water Partition Coefficient (log Kow): dependent upon form

Fish Bioconcentration Factor: 47 (1/kg)

Summary of Transport and Fate

Nickel is one of the most common of the heavy metals occurring in surface waters. Although nickel can exist in oxidation states of -1, 0, +1, +2, +3, and +4, under usual conditions in surface waters the divalent cation greatly predominates and is generally considered the most toxic. Alkalinity, hardness, salinity, pH, temperature, and complexing and adsorbing agents such as humic acids influence the oxidation state, toxicity, and availability of the total nickel pool. Nickel content in public water supplies is typically 5 ug/liter of less. In most aerobic aquatic environments, nickel may exist in solution as hydroxide, carbonate, sulfate and organic complexes. Some of the nickel in solution may be coprecipitated with hydrous metals oxides or sorbed onto organic material. The ratio of the dissolved and precipitated nickel is likely controlled by sorption to hydrous iron or manganese oxides. These same oxides in soils also function in the same manner, higher proportions of iron and manganese oxides increase the sorption of nickel. Soils rich in organic matter may enhance the mobility of nickel through complexation. Nonurban ambient air ranges from 0.002 to 0.008 ug/m^3 while urban air may average 0.021 ug Ni/m^3. In the atmosphere, nickel occurs as a result of industrial processes and is expected to be present as dusts or fumes. Any chemical interaction should result in the formation of nickel oxides. The principal removal mechanisms for atmospheric nickel are wet and dry deposition. EPA has published a guidance

level for Ni in water of 150 ug Ni/L. Nickel demonstrates a potential for groundwater contamination as a leachate from hazardous waste sites.

Summary of Health Effects

The toxicity of nickel or nickel salts through oral intake is low, ranking with such elements as zinc, chromium, and manganese. Nickel salts exert their action mainly by gastrointestinal irritation and not by inherent toxicity. The cause of this relative nontoxicity appears to be a mechanism in mammals that limits intestinal absorption. Nickel is probably essential for humans (ca 50 ug Ni/day). Nickel dermatitis is a relatively common form of nickel toxicity and it has been suggested that oral ingestion of nickel maybe of greater importance than external in maintaining hand eczema. Nickel has been reported to be carcinogenic by inhalation (e.g. nickel carbonyl) but not via oral injestion. An oral AIS of 1.4 mg/day and an oral AIC of 0.7 mg/day have been estimated for humans. The lack of data concerning the oral carcinogenicity of nickel would correspond to an IARC group 3 or a CAG group D.

CHEMICAL DATA SHEET

Chemical Name: Trichloroethene
Synonym: Trichloroethylene

CAS # 79-01-6

Molecular Weight: 131.5

Normal Physical State: Mobile liquid

Specific Gravity: 1.46 @ 68° F

Solubility (water): 1,100 mg/L @ 77° F

Boiling Point: 189° F

Melting Point: -99° F

Vapor Pressure: 57.9 mm Hg @ 68° F

Vapor Density: 4.53

Flash Point: 90° F

Autoignition Point: 788° F

Henry's Law Constant: 9.03×10^{-3} $atm\text{-}m^3/mole$

Organic Carbon Partition Coefficient (Koc): 126 ml/g

Octanol - Water Partition Coefficient (log Kow): 2.38

Biodegradation Factor: 10.6 1/g

Summary of Transport and Fate

Trichloroethene (TCE) is a multimedia environmental pollutant. Reaction with hydroxyl radicals is the principal mechanism by which TCE is scavenged from the atmosphere. The reaction produces carbon monoxide, carbon dioxide, carboxylic acid and hydrochloric acid. TCE reaches the atmosphere because of its high volatily. Within an aquatic environment TCE adsorbs to organic substances. In subsurface soil, some microbial degradation occurs but is not of major significance. TCE leaches into the groundwater readily, is a common contaminant of groundwater at hazardous waste sites, and is present in ambient air (ca. 1 ppb), potable water (ca. 0.5 ppb) and in various foodstuffs (ca. 9 ppt). TCE has no known natural sources.

Summary of Health Effects

Using EPA's classification criteria, TCE should be considered a probable human carcinogen (Group B2), although the available epidemiologic data remain inadequate to refute or demonstrate a human carcinogenic potential. TCE has been shown to carcenogenic to mice and rats with the inhalation route far more effective than the oral route. It is probable that TCE metabolites are the active carcinogenic agents. The recommended upper-limit incremental unit risk for humans exposed for a 70-year lifetime to a 1 ug/m^3 airborne concentration of TCE is 1.7×10^{-6}. For the oral route, a carcinogenic potency of 0.011 $(mg/kg/day)^{-1}$ has been computed. A low acute toxicity has been evidenced, around 6 g/kg for the oral LD_{50}. Other chronic exposure effects in animals include renal and hepatic toxicity, neurotoxicity, and dermatological reactions.

CHEMICAL DATA SHEET

Chemical Name: Tetrachloroethylene
Synonyms: Perchloroethylene
PERC

CAS # 127-18-4

Molecular Weight: 166 g/mole

Specific Gravity: 1.631

Solubility (water): 150 mg/L

Boiling Point: 250° F

Melting Point: 8° F

Vapor Pressure: 17.8 mm Hg

Vapor Density: 5.8

Flash Point: Not combustible

Autoignition Point: NA

Henry's Law Constant: 259 atm-m ^{3}/mole

Organic Carbon Partition Coefficient (KOC): 364 ml/g

Octanol-Water Coefficient (log Kow): 2.6

Fish Bioconcentration Factor: 31 l/kg

Summary of Transport and Fate

Tetrachloroethylene (PERC) is widely used as a solvent, and in such use, most is lost to the atmosphere through volatilization, with the reminder to incineration or solid waste disposal or released to ground and surface waters. In the atmosphere, PERC undergoes slow photochemical degradation (lifetime less than 1 year). This hydroxyl radical initiated decomposition yields include dichloroacetyl chloride and phosgene. PERC has been detected in surface and drinking water, generally at levels between 1 and 2 ppb. Contamination of soils and groundwater occur at hazardous waste sites. The CERCLA hazard rating for PERC persistence is a 2.

Summary of Health Effects

PERC inhalation or ingestion may cause gastric disturbances, narcosis, liver and kidney damage and peripheral neuropathy. Epidemiological evidence in humans is considered to be inadequate for carcinogen risk assessment. Animal evidence of carcinogenicity is limited because of positive results in only one strain of mice of a type of tumor that is common and difficult to interpret. PERC probably belongs in the overall weight-of-the-evidence category C (possible human carcinogen) rather than B 2 (probable human carcinogen).

APPENDIX C

HEALTH ASSESSMENT WORKSHEETS

TABLE C-1. Scoring for Indicator Chemical Selection: Calculation of CT[a] and IS[b] Values for Carcinogenic Effects.

Chemical	Ground Water CT[a]		Surface Water* CT		Soil* CT		Air* CT		IS[b] Value		Tentative Rank	
	Max	Rep	Max	Rep	Max	Rep	Max	Rep	Max	Rep	Max	Rep
Trichloroethene	1.4E+00	4.4E-02	-	-	-	-	-	-	1.4E+00	4.4E-02	1	1
Tetrachloroethene	1.1E-02	1.4E-03	-	-	-	-	-	-	1.1E-02	1.4E-03	2	2
Benzene	6.1E-02	6.7E-03	-	-	-	-	-	-	6.1E-02	6.7E-03	3	3
Methylene Chloride	-	-	-	-	-	-	-	-	-	-	4	4

* Contaminants were not reported in other media.
a denotes product of concentration x toxicity constant
b denotes indicator score

Table C-2. Scoring for Indicator Chemical Selection: Calculation of CT and IS Values for Noncarcinogenic Effects.

Chemical	Ground Water CT		Surface Water* CT		Soil* CT		Air* CT		IS Value		Tentative Rank	
	Max	Rep	Max	Rep	Max	Rep	Max	Rep	Max	Rep	Max	Rep
Barium	1.1E+02	1.3E+01	-	-	-	-	-	-	1.1E+02	1.3E+01	1	1
Trichloroethene	3.5E+02	1.1E+01	-	-	-	-	-	-	3.5E+02	1.1E+01	2	2
Nickel	8.1E+00	7.8E-01	-	-	-	-	-	-	8.1E+00	7.8E-01	3	3
Benzene	9.3E-01	1.0E-01	-	-	-	-	-	-	9.3E-01	1.0E-01	4	4
Lead	5.2E-01	9.4E-02	-	-	-	-	-	-	5.2E-01	9.4E-02	5	5
Toluene	2.4E-01	3.8E-02	-	-	-	-	-	-	2.4E-01	3.8E-02	6	6
Trans-1,2 Dichloroethene	2.4E-01	1.6E-02	-	-	-	-	-	-	2.4E-01	1.6E-02	7	7
Methyl Chloride	1.5E-02	3.3E-03	-	-	-	-	-	-	1.5E-02	3.3E-03	8	8
Tetrachloroethene	1.2E-02	1.6E-03	-	-	-	-	-	-	1.2E-02	1.6E-03	10	9
Chromium VI	-	-	-	-	-	-	-	-	1.4E-02	4.4E-04	9	10

* Contaminants were not reported in other media.

Table C-3. Preliminary Release Source Analysis for Baseline Site Conditions.

Release/ Contact Medium	Currently Contaminated	Potential Release Sources	Release Mechanisms	Release Time Frame	Release Likelihood and Amount
Air	No	Contaminated surface water	Volatil-ization	Continuous long-term	Probable low
Surface Water	No	Contaminated groundwater	Seepage	Continuous long-term	Definite moderate
Ground Water	Yes	Contaminated subsurface soil	Percol-ation	Continuous long-term	Definite moderate
Surface Soil	No	None-See Note 1			

Note 1 - Only subsurface soil is contaminated. No further consideration of surface soil as a release/contact medium or source.

Table C-4. Matrix of Potential Exposure Pathways.

Release/ Transport Medium	Exposure Point	Exposure Route	Number of People	Pathway Complete
Groundwater				
Perched	Shallow wells used for non-consumptive domestic use (See note 1.)	Ingestion of irrigated crops	N/A	No
		Inhalation & skin contact from non-consumptive uses	N/A	No
Regional	Workplaces at Tinker AFB	Ingestion of water	22,500 (See note 2.)	Yes
		Inhalation & skin contact from showers and industrial processes	2,500 (See note 3.)	Yes
Surface Water	At and below seepage area to Soldier Creek	Ingestion of aquatic organisms	7,500 (See note 4.)	No
		Dermal contact	5,300 (See note 5.)	No
Air	At and below seepage area to Soldier Creek	Inhalation/ Volatilization from surface water	5,300 (See note 5)	No

Note 1 - Mr. Doug Armstrong of the Oklahoma City-County Health Department on October 14, 1987 stated that his Department had surveyed an area near Tinker and could find no shallow wells using the perched water table for consumptive or non-consumptive uses. No further consideration of perched groundwater as a potential exposure pathway.

Note 2 - This value provided in the Building 3001 Remedial Investigation report (USACE, 1987) and is the total workforce at Tinker. 20,000 of these individuals are exposed for 45 hours per week (four 11-hour workdays) and 2,500 individuals are residents of the base and have continuous exposure.

Note 3 - This value provided in the Building 3001 Remedial Investigation report (USACE, 1987) and is the number of individuals who are residents of Tinker AFB.

Table C-4. Matrix of Potential Exposure Pathways. (Continued)

Release/ Transport Medium	Exposure Point	Exposure Route	Number of People	Pathway Complete

Note 4 - This number provided in census information. It is the number of people who fish in that region of Soldier Creek and was initially assumed to be people under 16 years of age. EPA does not recognize fish consumption by children, so these individuals were assumed to be adults with 70-kg body weight.

Note 5 - This is the number of people who live within 0.5 miles of the stream below the seepage area. It is assumed these individuals use that region of Soldier Creek for contact recreation. Population numbers were developed through census information.

Table C-5. Estimated Short-Term Air Concentrations (ug/cu m).

Chemical	100 m Best Estimate	500 m Best Estimate	100 m Conservative Estimate	500 m Conservative Estimate
Benzene	N/A	N/A	N/A	N/A
Trichloroethene	N/A	N/A	N/A	N/A
Tetrachloroethene	N/A	N/A	N/A	N/A
Nickel	0	0	0	0
Hexavalent Chromium	0	0	0	0
Lead	0	0	0	0
Barium	0	0	0	0

Note 1 - This table for information only. EPA has advised not to use short-term estimates for this RA. Furthermore, short-term contamination of surface water (via groundwater) will not occur and no air contamination through volatilization is possible.

Note 2 - All metals non-volatile at ambient temperature/pressure.

Table C-6. Estimated Short-term Groundwater Concentrations (ug/l).

Chemical	Nearest Residential Well		Nearest Municipal Well Field (Tinker wells)	
	Best Estimate	Conservative Estimate	Best Estimate	Conservative Estimate
Benzene	0	0	<0.5	0.5
Trichloroethene	0	0	1.9	3.8
Tetrachloroethene	0	0	0.7	1.4
Nickel	0	0	25	50
Hexavalent Chromium	0	0	10	20
Lead	0	0	45	90
Barium	0	0	680	1360

Note 1 - Best estimate for nearest municipal well field (Tinker wells) are actual values reported in the Building 3001 Remedial Investigation Report (USACE, 1987).

Note 2 - Conservative estimate is best estimate with a 100% safety factor applied.

Note 3 - No values used for residential wells because no short-term contamination has occurred.

Table C-7. Estimated Long-term Air Concentrations (mg/cu m).

Chemical	100 m Best Estimate	500 m Best Estimate	100 m Conservative Estimate	500 m Conservative Estimate
Benzene	1.0E-6	6.0E-8	3.3E-6	1.2E-7
Trichloroethene	4.0E-4	2.0E-4	4.7E-4	2.7E-5
Tetrachloroethene	4.1E-6	2.4E-7	1.0E-5	4.3E-7
Nickel	0	0	0	0
Hexavalent Chromium	0	0	0	0
Lead	0	0	0	0
Barium	0	0	0	0

Note 1 - All metals non-volatile at ambient temperature/pressure.

Note 2 - Calculation of air concentration at water/air interface made using methodology described in Environmental Science and Technology, November, 1980, pg. 1332. Rate constants of VOC's in the article were used in the first order reaction rate:

$$C(x) = Co\ e^{-kt}$$

Where: C(x) = concentration of contaminant in water following time (t)
Co = the initial concentration of contaminant in water
k = the decay rates developed from the ES&T article
t = time (one hour volatilization time was used in computing estimates)

Estimates of air concentration made by converting total quantity (in ug/l) of compound diffused from the water in 1 hour to air concentration, as follows:

ug/l divided by 1000=mg/l=ppm x (molecular weight divided by .02445) = ug/cubic meter divided by 1000 = mg/cubic meter

Estimates of concentration at 100 m and 500 m made using methodology shown in App. A of Environmental Risk Assessment Case Study Handbook:

$$C(x) = \frac{Q}{3.14\ abc}$$

where C(x) =concentration of contaminant at 100 m or 500 m
Q = release rate of substance (mass/time) assume volume=time
a = dispersion coefficient in the lateral direction (distance)
b = dispersion coefficient in the vertical direction (distance)
c= mean wind speed (distance/time)
and a stability level D and wind speed=1 meter/second were assumed

Table C-8. Estimated Long-term Groundwater Concentrations (ug/l).

Chemical	Nearest Residential Well		Nearest Municipal Well Field (Tinker wells)	
	Best Estimate	Conservative Estimate	Best Estimate	Conservative Estimate
Benzene	0	0	0.8	3
Trichloroethene	0	0	16.7	30
Tetrachloroethene	0	0	3.5	13
Nickel	0	0	47	70
Hexavalent Chromium	0	0	16	20
Lead	0	0	27	50
Barium	0	0	700	800

Note - Residential wells will not be impacted by contaminants during the 70-year evaluation period.

Table C-9. Estimated Long-term Surface Water Concentrations (ug/l).

Chemical	Best Estimate	Conservative Estimate
Benzene	<5	<5
Trichloroethene	500	600
Tetrachloroethene	5	8
Nickel	200	200
Hexavalent Chromium	7000	8000
Lead	100	120
Barium	1500	1500

Note 1 - Best estimate obtained by using 50-year value from modeled data.

Note 2 - Conservative estimate obtained by using 70-year value from modeled data.

Note 3 - Concentration values in the surface water do not reflect dilution making estimates a maximum expected concentration.

Table C-10. Contaminant Concentrations at Exposure Points.

Chemical	Release Medium	Exposure Point	Short-Term Concentration Best Estimate	Short-Term Concentration Conservative Estimate	Long-Term Concentration Best Estimate	Long-Term Concentration Conservative Estimate
Benzene	Air	Soldier Creek	N/A	N/A	1.0E-6	3.3E-6
	Groundwater	Tinker wells	<0.5	0.5	0.8	3.0
	Surface water	Soldier Creek	N/A	N/A	<5	<5
Trichloroethene	Air	Soldier Creek	N/A	N/A	4.0E-4	4.7E-4
	Groundwater	Tinker wells	1.9	3.8	16.7	30
	Surface water	SoldierCreek	N/A	N/A	500	600
Tetrachloroethene	Air	Soldier Creek	N/A	N/A	4.1E-6	1.0E-5
	Groundwater	Tinker wells	0.7	1.4	3.5	13
	Surface water	SoldierCreek	N/A	N/A	5	8
Nickel	Air	SoldierCreek	0	0	0	0
	Groundwater	Tinker wells	25	50	47	70
	Surface water	Soldier Creek	N/A	N/A	200	200
Hexavalent Chromium	Air	Soldier Creek	0	0	0	0
	Groundwater	Tinker wells	10	20	16	20
	Surface water	Soldier Creek	N/A	N/A	7000	8000
Lead	Air	Soldier Creek	0	0	0	0
	Groundwater	Tinker wells	45	90	27	50
	Surface water	Soldier Creek	N/A	N/A	100	120
Barium	Air	Soldier Creek	0	0	0	0
	Groundwater	Tinker wells	680	1360	700	800
	Surface water	Soldier Creek	N/A	N/A	1500	1500

Note - Water values in ug/l, air values in mg/cubic meter.

Table C-11. Comparison of Applicable or Relevant and Appropriate Requirements to Estimated Exposure Point Concentration. (Exposure Point: Seepage area at Soldier Creek - Inhalation).

Chemical	Applicable or Relevant and Appropriate Requirement	Requirement Concentration (mg/cu m)	Projected Exposure Point Concentration (mg/cu m)	Short-term (S) or Long-term (L) Concentration	Concentration: Standard Ratio
Benzene	MAAC	0.03	N/A	S	N/A
			1.0E-6	L	3.3E-8
Trichloroethene	MAAC	5.40	N/A	S	N/A
			4.0E-4	L	1.5E-6
Tetrachloroethene	MAAC	3.35	N/A	S	N/A
			4.1E-6	L	1.2E-8
Nickel	None - See Note 1				
Hexavalent Chromium	None - See Note 1				
Lead	None - See Note 1				
Barium	None - See Note 1				

Note 1 - Volatilization is the only route of air contamination; no dust or fumes. Metals not volatile at ambient temperature and pressure and thus, no ARAR's.

Note 2 - Best estimate value used for long-term concentration in accordance with worksheet instructions from Risk Assessment Case Study Manual.

Note 3 - MAAC are the maximum ambient air concentration under the state of Oklahoma's Air Toxics Program.

Table C-12. Comparison of Applicable or Relevant and Appropriate Requirements to Estimated Exposure Point Concentration. (Exposure Point: Soldier Creek Surface Water - Oral).

Chemical	Applicable or Relevant and Appropriate Requirement	Requirement Concentration (mg/l)	Projected Exposure Point Concentration (mg/l)	Short-term (S) or Long-term (L) Concentration	Concentration: Standard Ratio
Benzene	See Note 1.				
Trichloroethene	See Note 1.				
Tetrachloroethene	See Note 1.				
Nickel	See Note 1.				
Hexavalent Chromium	See Note 1.				
Lead	See Note 1.				
Barium	See Note 1.				

Note 1 - Drinking water ARARs not appropriate because ingestion of fish and skin/water absorption are only exposure mechanisms for this site. No ARAR's for these exposure methods. Risk comparison based on other criterion shown on Table C-29. Air inhalation for seepage area shown on additional worksheet.

Table C-13. Comparison of Applicable or Relevant and Appropriate Requirements to Estimated Exposure Point Concentration. (Exposure Point: Tinker AFB Municipal Waterwells - Oral)

Chemical	Applicable or Relevant and Appropriate Requirement	Requirement Concentration (mg/l)	Projected Exposure Point Concentration (mg/l)	Short-term (S) or Long-term (L) Concentration	Concentration: Standard Ratio
Benzene	MCL	0.005	<0.0005	S	<0.10
			0.0008	L	0.16
Trichloroethene	MCL	0.005	0.0019	S	0.38
			0.0167	L	3.34
Tetrachloroethene	--	--	0.0007	S	--
			0.0035	L	
Nickel	PG	0.015	0.025	S	1.70
			0.047	L	3.10
Hexavalent Chromium	MCL	0.05	0.01	S	0.20
			0.016	L	0.32
Lead	MCL	0.05	0.045	S	0.90
			0.0027	L	0.054
Barium	MCL	1.0	0.68	S	0.68
			0.70	L	0.70

Note 1 - Best estimate value used for both short- and long-term concentration in accordance with worksheet instructions from Risk Assessment Case Study Manual.

Table C-14. Comparison of Other Criteria, Advisories, and Guidance to Estimated Exposure Point Concentration. (Exposure Point: Seepage Area at Soldier Creek. - Inhalation)

Chemical	Applicable or Relevant and Appropriate Requirement	Requirement Concentration (mg/cu m)	Projected Exposure Point Concentration (mg/cu m)	Short-term (S) or Long-term (L) Concentration	Concentration: Standard Ratio
Benzene	Y	None			
Trichloroethene	Y	None			
Tetrachloroethene	Y	None			
Nickel	Not Applicable				
Hexavalent Chromium	Not Applicable				
Lead	Not Applicable				
Barium	Not Applicable				

Table C-15. Comparison of Other Criteria, Advisories, and Guidance to Estimated Exposure Point Concentration. (Exposure Point: Tinker AFB Municipal Waterwells - Oral).

Chemical	Applicable or Relevant and Appropriate Requirement Available	Other Criterion Being Considered	Value of Criterion (mg/l)	Projected Exposure Point Concentration (mg/l)	Short-term (S) or Long-term (L) Concentration	Concentration: Standard Ratio
Benzene	Y	None				
Trichloroethene	Y	None				
Tetrachloroethene	N	DWHA (Note 1)	6.8	0.0007 0.0035	S (Note 3) L	0.001 0.0005
Nickel	Y	DWHA	0.350	0.025 0.047	S L	0.0025 0.0047
Hexavalent Chromium	Y	DWHA	0.17	0.01 0.016	S L	0.06 0.09
Lead	Y	DWHA	0.01 (Note 2)	0.045 0.027	S L	4.5 2.7
Barium	Y	DWHA	1.8	0.68 0.70	S L	0.38 0.39

Note 1 - DWHA criterion are for longer-term or lifetime exposure of a 70-kg adult. This means the short term values are conservative.

Note 2 - Value obtained by extrapolating 20 ug/day to 2 liter/day average adult water intake.

Note 3 - Short-term values shown for information only. EPA has advised not to use short-term estimates for this RA.

Table C-16. Comparison of Other Criteria, Advisories, and Guidance to Estimated Exposure Point Concentration. (Exposure Point: Soldier Creek Surface Water - Inhalation).

Chemical	Applicable or Relevant and Appropriate Requirement Available	Other Criterion Being Considered	Value of Criterion (mg/kg/day)	Projected Exposure Point Concentration	Short-term (S) or Long-term (L) Concentration	Concentration: Standard Ratio
Benzene	N	PF-HEA	5.2E-2	See Note 1.	L	-
Trichloroethene	N	PF-HEA	1.1E-2	"	L	-
Tetrachloroethene	N	PF-HEA	5.1E-2	"	L	-
		AIC	2.0E-2	"	L	-
Nickel	N	AIC	1.0E-2	"	L	-
Hexavalent Chromium	N	AIC	5.0E-3	"	L	-
Lead	N	AIC	1.4E-3	"	L	-
Barium	N	AIC	5.1E-2	"	L	-

Note 1. - Exposure related to bioconcentration factor in aquatic organisms and intake by exposed population. These values will be calculated on following sheets.

Table C-17. Calculate Air Intakes. (Exposure Point - 100 meter radius of seepage areas).

Chemical		Human Intake Factor (cu m/kg/day)	Short-term Concentration (mg/cu m)	Subchronic Daily Intake (mg/kg/day)	Short-term Duration (year)	Long-term Concentration (mg/cum)	Chronic Daily Intake (mg/kg/day)
Benzene	A	.29	N/A	N/A	N/A	1.0E-6	2.9E-7
	C	.5	N/A	N/A	N/A	1.0E-6	5.0E-7
Trichloroethene	A	.29	N/A	N/A	N/A	4.0E-4	1.2E-4
	C	.5	N/A	N/A	N/A	4.0E-4	2.0E-4
Tetrachloroethene	A	.29	N/A	N/A	N/A	4.1E-6	1.2E-6
	C	.5	N/A	N/A	N/A	4.1E-6	2.1E-6
Nickel	A	.29	N/A	N/A	N/A	0	0
	C	.5	N/A	N/A	N/A	0	0
Hex chromium	A	.29	N/A	N/A	N/A	0	0
	C	.5	N/A	N/A	N/A	0	0
Lead	A	.29	N/A	N/A	N/A	0	0
	C	.5	N/A	N/A	N/A	0	0
Barium	A	.29	N/A	N/A	N/A	0	0
	C	.5	N/A	N/A	N/A	0	0

Note 1 - Best estimate concentration values used in accordance with instructions of SPHEM.

Note 2 - Human Intake Factor calculated using values suggested in SPHEM; volume of air inspired daily equals 20 cubic meters for adults and 5 cubic meters for children and body weight of 70-kg for adults and 10-kg for children.

Note 3 - A designates values for adults, C designates values for children.

Table C-18. Calculate Intake of Contaminated Fish From Surface Water. (Exposure Point - Soldier Creek and N. Canadian River Below Seepage Area)

Chemical	Fish BCF	Human Intake Factor (kg fish/kg/day)	Short-term Concentration (mg/l)	Subchronic Daily Intake (mg/kg/day)	Short-term Duration (years)	Long-term Concentration (mg/l)	Chronic Daily Intake (mg/kg/day)
Benzene	5.2	0.00009	0	0	-	<5E-3	1.2E-6
Trichloroethene	10.6	0.00009	0	0	-	0.5	4.9E-4
Tetrachloroethene	31	0.00009	0	0	-	5E-3	1.4E-5
Nickel	47	0.00009	0	0	-	0.2	8.5E-4
Hex chromium	16	0.00009	0	0	-	7.0	1.0E-2
Lead	49	0.00009	0	0	-	0.1	4.6E-4
Barium	None						

Note 1 - BCF values for fish obtained from SPHEM.

Note 2 - Calculations for adults only; assumed no consumption of fish by small children.

Note 3 - No short-term concentrations were considered in surface water since the contaminant plume has not reached East Soldier Creek.

Table C-19. Calculate Groundwater Intakes. (Exposure Point - Tinker AFB Municipal Wells).

Chemical		Human Intake Factor (1/kg/day)	Short-term Concentration (ug/1)	Subchronic Daily Intake (ug/kg/day)	Short-term Duration (year)	Long-term Concentration (ug/1)	Chronic Daily Intake (ug/kg/day)
Benzene	A	.029	<0.5	7.3E-3	0.5 year	0.8	2.3E-2
	C	.1	<0.5	2.5E-2	0.5 year	0.8	0.08
Trichloroethene	A	.029	1.9	5.5E-2	0.5 year	16.7	0.48
	C	.1	1.9	0.19	0.5 year	16.7	1.67
Tetrachloroethene	A	.029	0.7	2.0E-2	0.5 year	3.5	0.1
	C	.1	0.7	0.07	0.5 year	3.5	0.35
Nickel	A	.029	25	0.73	0.5 year	47	1.4
	C	.1	25	2.5	0.5 year	47	4.7
Hex chromium	A	.029	10	0.29	0.5 year	16	0.5
	C	.1	10	1.0	0.5 year	16	1.6
Lead	A	.029	45	1.3	0.5 year	27	0.78
	C	.1	45	4.5	0.5 year	27	2.70
Barium	A	.029	680	20.7	0.5 year	700	20.3
	C	.1	680	68.0	0.5 year	700	70.0

Note 1 - Amount of water ingested daily and average body weights obtained from values suggested in SPHEM. 2 liters daily for adults and 1 liter daily for children; average body weight for adults is 70-kg and for children is 10 kg. intakes in ug/kg/day.

Note 2 - A designates values for adults, C designates values for children.

Table C-20. Pathways Contributing to Total Exposure.

Exposure Point	Exposure Pathways Contributing to Total Exposure	Comments
1. Soldier Creek at and below seepage area.	Air Inhalation	Long-Term only
	Fish Ingestion	Adult and long-term only
	Dermal Absorption	Not quantified Long-term only
2. Residents/workers at Tinker AFB	Ground-water ingestion	Short- and long-term
	Dermal absorption	Not quantified
	Air Inhalation	Not quantified

Table C-21. Total Subchronic Daily Intake (SDI) Calculation. (Total Exposure Point: Seepage area on Soldier Creek - Oral. Number of People: 7500).

Chemical	Ground-Water SDI	Surface Water SDI	Fish Ingestion SDI	Total Oral SDI	Total Air SDI
Benzene	N/A	N/A	N/A	N/A	N/A
Trichloroethene	N/A	N/A	N/A	N/A	N/A
Tetrachloroethene	N/A	N/A	N/A	N/A	N/A
Nickel	N/A	N/A	N/A	N/A	N/A
Hex Chromium	N/A	N/A	N/A	N/A	N/A
Lead	N/A	N/A	N/A	N/A	N/A
Barium	N/A	N/A	N/A	N/A	N/A

Note 1 - N/A is Not applicable. No short term exposure at this exposure point.

Table C-22. Total Subchronic Daily Intake (SDI) Calculation. (Total Exposure Point: Soldier Creek below Seepage Area. Number of People: 7500).

Chemical	Ground-Water SDI	Surface Water SDI	Fish Ingestion SDI	Total Oral SDI	Total Air SDI
Benzene	N/A	N/A	N/A	N/A	N/A
Trichloroethene	N/A	N/A	N/A	N/A	N/A
Tetrachloroethene	N/A	N/A	N/A	N/A	N/A
Nickel	N/A	N/A	N/A	N/A	N/A
Hex Chromium	N/A	N/A	N/A	N/A	N/A
Lead	N/A	N/A	N/A	N/A	N/A
Barium	N/A	N/A	N/A	N/A	N/A

Note 1 - N/A is Not applicable. No short term exposure at this exposure point.

Table C-23. Total Subchronic Daily Intake (SDI) Calculation. (Total Exposure Point: Tinker AFB municipal wells. Number of People: 22,500).

Chemical	Ground-Water SDI	Surface Water SDI	Fish Ingestion SDI	Total Oral SDI	Total Air SDI
Benzene	7.3E-6	0	0	7.3E-6	0
Trichloroethene	5.5E-5	0	0	5.5E-5	0
Tetrachloroethene	2.0E-5	0	0	2.0E-5	0
Nickel	7.3E-4	0	0	7.3E-4	0
Hex Chromium	2.9E-4	0	0	2.9E-4	0
Lead	1.3E-3	0	0	1.3E-3	0
Barium	1.9E-2	0	0	1.9E-2	0

Note 1 - Adult exposure values only calculated.

Note 2 - Exposure periods differ between 2,500 residents of installation and 20,000 workers. Longer period for residents applied to both workers and residents, which increases conservative nature of estimate.

Note 3 - All values in mg/kg/day.

Table C-24. Total Chronic Daily Intake (CDI) Calculation. (Total Exposure Point: Soldier Creek at and below seepage area. Number of People: 7,500).

Chemical	Ground-Water CDI	Surface Water CDI	Fish Ingestion CDI	Total Oral CDI	Total Air CDI
Benzene	0	0	1.0E-6	1.0E-6	2.9E-7
Trichloroethene	0	0	5.0E-4	5.0E-4	1.2E-4
Tetrachloroethene	0	0	1.4E-5	1.4E-5	1.2E-6
Nickel	0	0	8.7E-4	8.7E-4	0
Hex Chromium	0	0	1.0E-2	1.0E-2	0
Lead	0	0	4.6E-4	4.6E-4	0
Barium	0	0	0	0	0

Note 1 - All values in mg/kg/day.

Note 2 - All assumptions from SPHEM; no consumption of fish by children, adult intake of freshwater fish = 6.5 g/day, and adult body weight = 70 kg.

Note 3 - Ingestion of surface water wat not considered since it is not a treated water supply source. Incidental ingestion was considered a minor component of ingestion and not quantified.

Table C-25. Total Chronic Daily Intake (CDI) Calculation. (Total Exposure Point: Total Exposure Point: Tinker AFB Municipal Waterwells. Number of People: 22,500).

Chemical	Ground-Water CDI	Surface Water CDI	Fish Ingestion CDI	Total Oral CDI	Total Air CDI
Benzene	2.3E-5	0	0	2.3E-5	0
Trichloroethene	4.8E-4	0	0	4.8E-4	0
Tetrachloroethene	1.0E-4	0	0	1.0E-4	0
Nickel	1.4E-3	0	0	1.4E-3	0
Hex Chromium	5.0E-4	0	0	5.0E-4	0
Lead	7.8E-4	0	0	7.8E-4	0
Barium	2.0E-2	0	0	2.0E-2	0

Note 1 - Adult exposure only calculated.

Note 2 - Exposure periods differ between 2,500 residents of installation and 20,000 workers. Longer period for residents applied to both workers and residents, which increases conservative nature of estimate.

Note 3 - All values in mg/kg/day

Note 4 - Dermal and inhalation exposure through showers, dishwashing, etc. not quantified.

Table C-26. Critical Toxicity Values.

Chemical	AIS (mg/kg/day)	AIC (mg/kg/day)	Carcinogenic Potency Factor (mg/kg/day)-1
Inhalation Route			
Benzene	-	-	2.6E-2 (A)
Trichloroethene	-	-	4.6E-3 (B2)
Tetrachloroethene	-	-	1.7E-3 (B2)
Ingestion Route			
Benzene	-	-	5.2E-2 (A)
Trichloroethene	-	-	1.1E-2 (B2)
Tetrachloroethene	-	2.0E-2	5.1E-2 (B2)
Nickel	2.0E-2	1.0E-2	-
Hex Chromium	2.5E-2	5.0E-3	-
Lead	-	1.4E-3	-
Barium	-	5.1E-2	-

Table C-27. Calculation of Subchronic Hazard Index. (Total Exposure Point: Seepage area on Soldier Creek)

Chemical	Inhalation			Oral		
	SDI	AIS	SDI:AIS	SDI	AIS	SDI:AIS
Benzene	N/A	N/A	N/A	N/A	N/A	N/A
Trichloroethene	N/A	N/A	N/A	N/A	N/A	N/A
Tetrachloroethene	N/A	N/A	N/A	N/A	N/A	N/A
Nickel	N/A	N/A	N/A	N/A	N/A	N/A
Lead	N/A	N/A	N/A	N/A	N/A	N/A
Hex Chromium	N/A	N/A	N/A	N/A	N/A	N/A
Barium	N/A	N/A	N/A	N/A	N/A	N/A

Sum of Inhalation SDI:AIS ratios - N/A
Sum of Oral SDI:AIS ratios - N/A
Sum Total of all ratios - N/A

Note 1 - No short term exposure from at this exposure point.

Table C-28. Calculation of Subchronic Hazard Index. (Total Exposure Point: Tinker AFB Municipal Waterwells).

Chemical	Inhalation			Oral		
	SDI	AIS	SDI:AIS	SDI	AIS	SDI:AIS
Benzene	N/A	N/A	N/A	7.3E-7	-	-
Trichloroethene	N/A	N/A	N/A	5.5E-5	-	-
Tetrachloroethene	N/A	N/A	N/A	2.0E-5	-	-
Nickel	N/A	N/A	N/A	7.3E-4	2.0E-2	3.6E-2
Lead	N/A	N/A	N/A	2.9E-4	-	-
Hex Chromium	N/A	N/A	N/A	1.3E-3	2.5E-2	5.2E-2
Barium	N/A	N/A	N/A	2.0E-2	-	-

Sum of Inhalation SDI:AIS ratios - N/A
Sum of Oral SDI:AIS ratios - 8.8E-2
Sum Total of all ratios - 8.8E-2

Note 1 - All values in mg/kg/day

Table C-29. Calculation of Chronic Hazard Index. (Total Exposure Point: Tinker AFB Municipal Waterwells - Oral).

Chemical	Inhalation			Oral		
	CDI	AIC	CDI:AIC	CDI	AIC	CDI:AIC
Benzene	See Note 1			2.3E-5	-	-
Trichloroethene	See Note 1			4.8E-4	-	-
Tetrachloroethene	See Note 1			1.0E-4	2.0E-2	5.0E-3
Nickel	See Note 2			1.4E-3	1.0E-2	0.14
Lead	See Note 2			7.8E-4	1.4E-3	0.55
Hex Chromium	See Note 2			5.0E-4	5.0E-3	0.10
Barium	See Note 2			2.0E-2	5.1E-2	0.39

Sum of Inhalation CDI:AIC ratios = N/A
Sum of Oral CDI:AIC ratios = 1.18
Sum Total of all ratios = 1.18

Note 1 - Inhalation exposure through showers, etc. not quantified for 2,500 base residents. No inhalation exposure projected for 20,000 base workers who are not residents.

Note 2 - No inhalation exposure for metals.

Table C-30. Calculation of Chronic Hazard Index. (Total Exposure Point: Soldier Creek at and below seepage point).

Chemical	Inhalation			Oral		
	CDI	AIC	CDI:AIC	CDI	AIC	CDI:AIC
Benzene	2.9E-7	-	-	1.0E-5	-	-
Trichloroethene	1.2E-4	-	-	5.0E-4	-	-
Tetrachloroethene	1.2E-6	-	-	1.4E-5	2.0E.2	7.0E-4
Nickel	0	1.0E-2	-	8.7E-4	1.0E-2	8.7E-2
Lead	0	5.0E-3	-	4.6E-4	1.4E-2	3.3E-2
Hex Chromium	0	1.4E-3	-	1.03-2	5.0E-3	2.0
Barium	0	5.1E-2	-	N/A	5.1E-3	-

Sum of Inhalation CDI:AIC ratios = N/A
Sum of Oral CDI:AIC ratios = 2.12
Sum Total of all ratios = 2.12

Note 1 - All values in mg/kg/day

Table C-31. Calculation of Risk From Potential Carcinogens. (Total Exposure Point: Tinker AFB Municipal Wells).

Chemical	Exposure Route	CDI (mg/kg/day)	x	Carcinogenic Potency Factor (mg/kg/day)-1	=	Route Specific Risk	Total Chemical-Specific Risk
Benzene	Oral	2.3E-5		5.2E-2		1.2E-6	1.2E-6
	Inhalation	0		2.6E-2		0	
Trichloroethene	Oral	4.8E-4		1.1E-2		5.3E-6	5.3E-6
	Inhalation	0		4.6E-3		0	
Tetrachloroethene	Oral	1.0E-4		5.1E-2		5.1E-6	5.1E-6
	Inhalation	0		1.7E-3		0	
Nickel	Oral	1.4E-3		None		0	0
	Inhalation	0		N/A		0	
Lead	Oral	7.8E-4		None		0	0
	Inhalation	0		N/A		0	
Hex Chromium	Oral	5.0E-4		None		0	0
	Inhalation	0		N/A		0	
Barium	Oral	2.0E-2		None		0	0
	Inhalation	0		N/A		0	

TOTAL UPPER BOUND RISK = 1.2E-5

Table C-32. Calculation of Risk From Potential Carcinogens. (Total Exposure Point: Soldier Creek at and below seepage point).

Chemical	Exposure Route	CDI (mg/kg/day)	x Carcinogenic Potency Factor (mg/kg/day)-1	= Route Specific Risk	Total Chemical-Specific Risk
Benzene	Oral	1.0E-6	5.2E-2	5.2E-8	6.0E-8
	Inhalation	2.9E-7	2.6E-2	8.0E-9	
Trichloroethene	Oral	5.0E-4	1.1E-2	5.5E-6	6.1E-6
	Inhalation	1.2E-4	4.6E-3	5.5E-7	
Tetrachloroethene	Oral	1.4E-5	5.1E-2	7.1E-7	7.1E-7
	Inhalation	1.2E-6	1.7E-3	2.0E-9	
Nickel	Oral	8.7E-4	None	0	0
	Inhalation	0	N/A	0	
Lead	Oral	4.6E-4	None	0	0
	Inhalation	0	N/A		
Hex Chromium	Oral	1.0E-2	None	0	0
	Inhalation	0	N/A	0	
Barium	Oral	0	None	0	0
	Inhalation	0	N/A	0	

TOTAL UPPER BOUND RISK = 6.9E-6

APPENDIX D

STANDARD ASSUMPTION VALUES USED IN DAILY INTAKE CALCULATIONS

STANDARD ASSUMPTION VALUES USED IN DAILY INTAKE CALCULATIONS

Parameter	Standard Value*
Average body weight, adult	70 kg
Average body weight, child	10 kg
Amount of water ingested daily, adult	2 liters
Amount of water ingested daily, child	1 liter
Amount of air breathed daily, adult	20 m^3
Amount of air breathed daily, child	5 m^3
Amount of freshwater fish consumed daily, adult	6.5 g

*Reference Superfund Health Evaluation Manual

APPENDIX E

PHYSICAL/CHEMICAL DATA OF MAJOR CONSTITUENTS OF BUILDING 3001 CONTAMINANT RELEASE

TABLE E-1. Physical and Chemical Data on Major Constituents of the Building 3001 Contaminant Release.

Chemical (CAS)	MW g/Mole	Solubility mg/l	Specific Gravity	Vapor Pressure (mmHg)	Henry's Law Constant	Koc ml/g	Log Kow	Mobility Description	Surface Water Halflife (days)	BCF
Acetone (67-64-1)	58	1,000,000	0.790	270	2.06E-05	2.2	-0.24	High	7	NA
Benzene (71-43-2)	78	1,750	0.879	95	5.59E-03	83	2.12	Moderate	1-6	5.2
1,1 Dichloroethene (75-35-4)	97	2,250	1.218	600	3.40E-02	65	1.84	Mod High	1-6	5.6
1,2 Dichloroethene (540-59-0)	97	6,300	1.260	324	6.56E-03	59	0.48	High	1-6	1.6
1,2 Dichloroethane (107-06-2)	99	8,520	1.250	64	9.78E-04	14	1.48	High	0.2	1.2
Methylene chloride (74-87-3)	50	6,500	1.326	4,310	4.40E-02	35	0.95	High	10	
Chlorobenzene (108-90-7)	113	466	1.106	12	3.72E-03	330	2.84	Moderate	0.6	10
1,1,2,2 Tetrachloroethane (79-34-5)	168	2,900	1.338	5	3.81E-04	118	2.39	Mod High	0.04	42
Tetrachloroethene (127-18-4)	166	150	1.623	17.8	2.59E-02	364	2.60	Low	1-30	31
Vinyl chloride (75-01-4)	63	2,670	0.912	2,660	8.19E-02	57	1.38	Mod High	1-5	1.17
Xylene (1330-20-7)	106	198		10	7.04E-03	240	3.26	Low	1.5-9	
Toluene (108-88-3)	92	535	0.866	28	6.37E-03	300	2.73	Moderate	2-14.2	10.7
1,1,1 Trichloroethane (71-55-6)	133	1,500	1.338	123	1.44E-02	152	2.50	Moderate	0.14-7	5.6
Trichloroethene (79-01-6)	131	1,100	1.464	58	9.10E-03	126	2.38	Moderate	1-90	10.6
Phenol (108-95-2)	94	9,300	1.070	.034	4.54E-07	14.2	1.46	High	0.6-9	1.4
Bis (2 ethylhexyl) phthalate (117-81-7)	391								.007	
Di-butyl phthalate (84-74-2)	278	13		1.0E-05	2.82E-07	17E+04	5.6			
Barium (7440-39-3)	137									

TABLE E-1. Physical and Chemical Data on Major Constituents of the Building 3001 Contaminant Release. (Continued)

Chemical (CAS)	MW g/Mole	Solubility mg/l	Specific Gravity	Vapor Pressure (mmHg)	Henry's Law Constant	Koc ml/g	Log Kow	Mobility Description	Surface Water Halflife (days)	BCF
Cadmium (7740-43-9)	112					2.4	0			81
Chromium VI (7440-47-3)	52			0						16
Lead (7439-92-1)	207			0						49
Nickel (7440-02-0)	59			0						47
Mercury (7439-97-6)	201			2.00E-03						5500
Arsenic (7440-38-2)	75			0						44
Selenium (7782-49-2)	79			0						16

MW denotes molecular weight
KOC denotes octanol - carbon partition coefficient
KOW denotes octanol - water partition coefficient
BCF denotes biological concentration factor
Henry's Law Constant is reported in units of atm-m^3/mole

APPENDIX F

CHEMICAL DATA
FROM REMEDIAL INVESTIGATION

CHEMICAL DATA

Appendix F is the raw data used in the development of indicator chemicals. The data originated in the Draft Remedial Investigation Report of Tinker Air Force Base, Oklahoma (USACE, 1987). The data reports the concentration in parts per billion (ppb) from each monitoring well in each aquifer or portion of the regional Garber-Wellington aquifer. Denotations in the data are as follows:

N is the number of occurrences

ND is the number of samples that reported non-detection of a chemical

SD is the standard deviation of the sample concentrations

BG is the reported background level

DL is the reported detection limit

F is the frequency of occurrence of a chemical

Overall Mean is the mean of all values of the chemical detected from the combination of the three aquifers.

ARSENIC, TOTAL (ug/l) DL=1

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
3	34A	2	1-1A	4	34C
1	1-1B	43	34B	18	34D
58	M2	2	1-2A	5	34C
5	MM2	1	1-4A	6	35C
4	33A	5	1-5A	2	33C
2	1-5B	2	33B	2	33C
4	1-7B	12	32B	2	32C
1	33A	13	25C	1	1-8A
1	1-8B	7	25A	35	1-15C
2	32A	1	1-9A	43	1-14C
3	1-9B	2	24A	3	1-14C
44	25B	2	1-10A	1	1-12C
3	1-10B	4	23A	12	1-12C
28	1-30	1	22A	2	1-10C
4	1-31	3	1-12A		
6	1-12B	3	20A		
3	1-29	1	19A		
8	1-27	3	1-12A		
4	1-26	21	1-13A		
2	1-13B	12	1-15A		
3	19B	2	1-14A		
26	1-15B	3	1-14A		
5	1-14B				
3	1-14B				
N=24		N=22		N=14	
ND=13		ND=9		ND=2	
MEAN=9.3		MEAN=6.6		MEAN=9.8	
SD=14.7		SD=9.6		SD=13.4	
BG=10		BG=2		BG=2	

F=60/84
OVERALL MEAN=8.4

BARIUM, TOT (ug/1) DL=500

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
9700	MM2	1400	1-5A	660	35C
8300	M2	1900	1-6A	2300	35B
1700	35A	1400	1-7A	3000	34D
540	1-10B	12000	34B	1400	34C
800	33A	1000	33B	3500	1-10C
1300	1-11B	690	33B	1100	34C
720	1-12B	1800	32B	500	33C
1600	34A	970	25A	18000	1-12C
640	1-13B	870	25A	930	33C
840	32A	660	1-14A	580	32C
3300	1-14B	670	24A	900	25C
670	1-31	740	23A	27000	1-14C
18000	1-30	4600	1-15A	3400	1-14C
1900	1-15B	580	22A	1500	1-12C
13000	1-27	1100	1-1A	1300	1-10C
1300	1-1B	640	21A	530	1-10C
13000	1-26	740	1-5A		
3000	1-5B	1600	19A		
1000	25B	700	1-6A		
2300	23B	1000	1-7A		
3800	1-1B	1400	19A		
2800	1-2B	750	1-14A		
2300	23B	2000	1-3A		
1500	1-3B	1700	1-13A		
660	22B	550	1-4A		
2400	1-4B	24000	1-13A		
1600	21B	4000	1-5A		
730	1-5B	1500	1-19A		
960	1-7B				
1600	21B				
990	1-9B				
1200	19B				
890	1-14B				
N=33		N=28		N=16	
ND=7		ND=6		ND=2	
MEAN=3183.0		MEAN=2534.3		MEAN=4162.5	
SD=4250.3		SD=4757.9		SD=7411.5	
BG=1110		BG=663		BG=663	

F=77/93
OVERALL MEAN=3150.6

CADMIUM, TOTAL (ug/L) DL=8

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
8	34A	15	1-13A	10	25C
8	1-13B	13	34B	8	32C
13	1-14B	8	35B	15	1-14C
10	33A	8	1-12A	10	1-14C
13	1-30	10	1-15A	13	35C
8	1-31	10	1-5A	15	1-15C
8	32A	10	19A	13	34D
10	19B	8	1-5A	8	34C
8	1-1B			13	34C
8	1-3B			8	33C
10	33A			8	33C
10	35A			10	1-12C
8	1-5B			15	10c
13	1-7B				
10	34A				
8	1-12B				
20	M2				
N=17		N=8		N=13	
ND=20		ND=20		ND=6	
MEAN=10.2		MEAN=10.3		MEAN=10.9	
SD=3.14		SD=2.5		SD=2.7	
BG=10		BG=7.5		BG=7.5	

F=38/84
OVERALL MEAN=10.5

NON-SPECIATED CHROMIUM, TOT (ug/l) DL=10

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
120000	34A	60	1-1A	345	1-12C
58	1-1B	260	33B	120	33C
50	1-1B	1700	34B	170	33C
110	1-2B	390	32B	150	32C
58	1-3B	10	25A	950	1-15C
68	1-4B	10	21A	930	1-14C
38	1-31	40	1-5A	10	1-8A
80000	34A	25	1-5A	18	1-8A
210	1-5B	43	19A		
28	1-5B	35	19A		
100	33A	45	1-6A		
18	1-6B	15	1-14A		
300	32A	83	1-7A		
140	1-7B	23	1-14A		
1100	1-30	370	1-13A		
110	25B	55	1-9A		
90	1-9B	300	13B		
13	22B	50	1-10A		
68	21B	160	1-11A		
340	19B				
13	1-11B				
35	1-12B				
220	33A				
340	19B				
1200	19B				
13	1-13B				
45	1-14B				
240	1-14B				
N=28		N=19		N=8	
ND=6		ND=8		ND=7	
MEAN=7321.6		MEAN=193.4		MEAN=336.6	
SD=26737.5		SD=385.5		SD=386.5	
BG=10		BG=7.5		BG=7.5	

F=55/76
OVERALL MEAN=3843.1

LEAD, TOT (ug/l) DL=25

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
230	1-15B	30	1-1A	400	1-14C
60	1-1B	78	33B	580	1-15C
70	1-1B	250	34B	53	1-13C
43	1-27	25	1-2A	50	1-12C
43	1-2B	43	23A	150	1-10C
33	1-3B	80	32-B	25	1-8A
35	1-3B	85	1-15B		
40	1-31	120	1-5A		
110	33A	310	1-5A		
80	1-5B	50	25A		
73	1-12B	60	1-6A		
58	1-6B	48	24A		
95	32A	38	1-7A		
250	1-7B	53	22A		
570	1-30	35	20A		
40	1-26	43	1-9A		
50	1-9B	50	1-14A		
240	25B	45	1-10A		
30	1-10B	48	19A		
88	25B	70	19A		
28	1-11B	60	1-14A		
33	22B	68	1-12A		
63	1-13B	83	1-12A		
83	1-12B	410	1-13A		
120	1-14B				
63	1-14B				
65	19B				
58	19B				
58	20B				
50	21B				
N=30		N=24		N=6	
ND=3		ND=4		ND=1	
MEAN=95.3		MEAN=90.9		MEAN=209.7	
SD=107.5		SD=95.2		SD=228.5	
BG=51		BG=48		BG=48	

F=60/68

OVERALL MEAN=105.0

MERCURY, TOTAL (ug/l) DL=0.1

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
.3	1-1B	.2	1-2A	.4	1-10C
.1	1-7B	.1	1-5A	.4	1-12C
.4	1-10B	.2	1-6A		
		.6	1-10A		
		.7	1-11A		
N=3		N=5		N=2	
ND=30		ND=19		ND=8	
MEAN=0.27		MEAN=0.36		MEAN=0.4	
SD=0.15		SD=0.27		SD=0	
BG=<0.4		BG=<0.4		BG=<0.4	

F=10/67
OVERALL MEAN=0.34

NICKEL, TOT (ug/1) DL=10

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
63	1-31	63	1-1A	120	35C
310	1-1B	140	35B	380	34D
60	1-1B	580	34B	83	34D
190	32A	48	1-2A	70	34C
70	1-2B	320	33B	73	33C
48	MM2	35	1-3A	120	33C
340	1-3B	170	32B	78	32C
170	M2	18	1-4A	20	1-12C
160	1-4B	28	23A	390	1-12C
220	35A	230	1-5A	1900	1-15C
110	34A	63	1-5A	1100	1-14C
320	1-5B	35	25A	23	1-13C
70	34A	63	1-6A	63	1-12C
490	1-6B	30	24A	25	1-12C
530	33A	80	1-7A	50	1-10C
130	1-7B	40	22A	25	1-8A
100	33A	25	19A		
20	1-8B	45	19A		
450	1-15B	90	1-9A		
100	1-9B	45	1-14A		
60	1-12B	170	1-10A		
170	1-10B	28	1-14A		
100	1-5B	530	1-13A		
1100	1-30	240	1-11A		
140	1-11B	28	1-12A		
13	1-26				
45	1-12B				
75	1-12B				
23	1-26				
55	25B				
65	25B				
38	1-13B				
130	22B				
170	22B				
250	21B				
180	1-14B				
100	1-14B				
20	20B				
40	19B				
290	19B				
N=40		N=25		N=16	
ND=0		ND=0		ND=0	
MEAN=175.4		MEAN=131.7		MEAN=283.1	
SD=198.8		SD=152.5		SD=509.6	
BG=101		BG=33		BG=33	

F=81/81
OVERALL MEAN=183.2

SELENIUM, TOTAL (ug/l) DL=0.4

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
0.8	35A	0.8	24A	0.6	35C
3.0	1-8B	0.9	25A	4.0	1-8A
0.5	1-1B	0.4	23A	0.9	25C
0.8	1-29	0.5	1-9A	0.6	1-13C
0.8	32B	0.4	1-3A	0.6	1-14C
0.6	1-9B	2.0	1-2A	0.6	32C
0.6	1-4B	0.5	35B	0.7	33C
6.0	1-6B	0.6	33B	1.0	33C
3.0	1-7B	2.0	1-13A		
5.0	1-14B	0.9	1-1A		
1.0	33A	1.0	21A		
1.0	33A				
N=12		N=11		N=8	
ND=21		ND=15		ND=7	
MEAN=1.93		MEAN=0.91		MEAN=1.13	
SD=1.89		SD=0.58		SD=1.17	
BG=2.1		BG=0.5		BG=0.5	
		F=31/74			
		MEAN=1.36			

ACETONE (ug/l)

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
54	1-4B	370	1-2A	17	1-8A
49	1-8B	190	1-3A	100	1-13C
39	1-11B	240	1-4A	75	32C
1100	1-12B	220	1-5A	16	33C
870	1-13B	1400	1-6A		
1600	1-18	490	1-7A		
60	23B	390	1-9A		
95	M2	210	1-10A		
540	32A	47	1-13A		
190	35A	20	23A		
		59	32B		
		23	33B		
		200	35B		
N=10		N=13		N=4	
ND=36		ND=17		ND=13	
MEAN=459.7		MEAN=296.8		MEAN=52	
SD=553.9		SD=362.4		SD=42.2	
BG=0		BG=0		BG=0	

F=27/93
OVERALL MEAN=320.9

BENZENE

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
25	1-16	11	1-11A	430	25C
37	1-17			1	34C
15	1-18				
1000	M2				
580	25B				
5	1-27				
260	1-30				
1225	M1				
83	M2				
853	M3				
767	M4				
45	M5				
1535	M6				
7946	MA1				
N=14		N=1		N=2	
ND=37		ND=29		ND=15	
MEAN=1026.9		MEAN=11		MEAN=215.5	
SD=2056.2		SD=-		SD=303.3	
BG=0		BG=0		BG=0	

F=17/98
OVERALL MEAN=871.7

CARBON TETRACHLORIDE (ug/l) DL=5

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
5	33A	14	1-11A		
N=1		N=1		N=0	
ND=30		ND=27		ND=16	
MEAN=5		MEAN=14		MEAN=-	
SD=-		SD=-		SD=-	
BG=0		BG=0		BG=0	

F=2/75
OVERALL MEAN=9.5

CHLOROFORM (ug/1) DL=5

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
9	1-12B			8	35C
5	19B				
48	33A				
N=3		N=0		N=1	
ND=28		ND=28		ND=15	
MEAN=20.7		MEAN=-		MEAN=8	
SD=23.8		SD=-		SD=-	
BG=0		BG=0		BG=0	

F=4/75
OVERALL MEAN=17.5

CHLOROBENZENE (ug/L) DL=5

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
6	1-11B	10	32B	40	34C
32	1-12B	6	33B		
		35	34B		
		57	34B		
		940	1-11A		
N=2		N=5		N=1	
ND=28		ND=22		ND=13	
MEAN=19		MEAN=209.6		MEAN=40	
SD=18.4		SD=408.8		SD=-	
BG=0		BG=0		BG=0	

F=8/71
OVERALL MEAN=140.8

1,2 DICHLOROBENZENE (ug/1) DL=5

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
12	33A				
N=1		N=0		N=0	
ND=30		ND=28		ND=16	
MEAN=12		MEAN=-		MEAN=-	
SD=-		SD=-		SD=-	
BG=0		BG=0		BG=0	

F=1/75
OVERALL MEAN=12

1,1-DICHLOROETHANE (ug/l) DL=5

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
				3	34C
N=0		N=0		N=1	
ND=31		ND=28		ND=15	
MEAN=-		MEAN=-		MEAN=3	
SD=-		SD=-		SD=1.9	
BG=0		BG=0		BG=0	

F=1/75
OVERALL MEAN=3

1,2-DICHLOROETHANE (ug/l) DL=5

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
70	M2	150	1-7A	7	32C
390	33A	110	1-11A	3	34C
12	1-12B	25	1-14A		
		29	1-14A		
		67	32B		
N=3		N=5		N=2	
ND=28		ND=23		ND=14	
MEAN=157.3		MEAN=76.2		MEAN=5	
SD=203.6		SD=53.7		SD=2.8	
BG=0		BG=0		BG=0	

F=10/75
OVERALL MEAN=86.3

1,1-DICHLOROETHENE (ug/1) DL=5

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
9	33A	16	32B	1	34C
		12	33B		
		12	34B		
		13	34B		
N=1		N=4		N=1	
ND=30		ND=24		ND=15	
MEAN=9		MEAN=13.3		MEAN=1	
SD=-		SD=1.9		SD=-	
BG=0		BG=0		BG=0	

F=6/75
OVERALL MEAN=10.5

1,2 DICHLOROPROPANE (ug/1) DL=5

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
		36	1-11A		
N=0		N=1		N=0	
ND=31		ND=27		ND=16	
MEAN=-		MEAN=36		MEAN=-	
SD=-		SD=-		SD=-	
BG=0		BG=0		BG=0	

F=1/75
OVERALL MEAN=36

TRANS-1,2-DICHLOROETHENE (ug/l) DL=5

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
810	1-31	5	1-1A	35	1-15C
70	M2	21	1-2A	6	1-12C
120	33A	18	1-5A	12	35C
552	25B	220	1-7A	58	34C
5	1-8B	19	1-14A	36	34C
20	32A	7	1-9A	1	34D
25	1-9B	61	35B	46	32C
31	1-15B	1400	1-11A	7	14C
4600	1-12B	12	1-12A	40	1-12C
2100	1-12B	24	1-12A	7	1-13C
		11	1-14A		
		16	1-15A		
		16	19A		
		44	20A		
		930	32B		
		240	33B		
		47	34B		
		63	34B		
N=10		N=18		N=10	
ND=18		ND=11		ND=6	
MEAN=783.3		MEAN=175.2		MEAN=24.8	
SD=1495		SD=375.2		SD=20.4	
BG=0		BG=0		BG=0	

F=38/73
OVERALL MEAN=295.6

1,1,2,2-TETRACHLOROETHANE (ug/1) DL=5

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
460	1-31	19	1-11A		
		22	33B		
N=1		N=2		N=0	
ND=30		ND=26		ND=16	
MEAN=460		MEAN=21.5		MEAN=-	
SD=-		SD=2.1		SD=-	
BG=0		BG=0		BG=0	

F=3/75
OVERALL MEAN=167.7

TETRACHLOROETHENE (ug/l) DL=5

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
14	19B	33	32B	2	34D
12	1-8B	7	19A	28	32C
170	33A	1200	33B	7	34D
10	1-5B	130	34B	10	35C
12	1-8B	950	1-11A	25	34C
				21	34C
N=5		N=5		N=6	
ND=24		ND=18		ND=9	
MEAN=43.6		MEAN=464		MEAN=15.5	
SD=70.7		SD=566.6		SD=10.6	
BG=0		BG=0		BG=0	

F=16/67
OVERALL MEAN=164.4

TOLUENE (ug/1) DL=1

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
2200	M2	6	19A	280	1-13C
560	25B	6	1-11A	49	1-14C
390	1-30	84	1-13A	13000	25C
47120	M1	7	33B	1	34C
125	M2			1	34D
41715	M3				
9134	M4				
227	M5				
21075	M6				
2815	MA1				
N=10		N=4		N=5	
ND=37		ND=25		ND=13	
MEAN=12536.1		MEAN=25.8		MEAN=2666.2	
SD=18042.5		SD=38.8		SD=5777,2	
BG=0		BG=0		BG=0	

F=19/94
OVERALL MEAN=7305.0

1,1,1-TRICHLOROETHANE (ug/1) DL=5

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
6	1-1B	10	32B	1	34D
96	1-12B	100	1-11A		
		7	19A		
N=2		N=3		N=1	
ND=29		ND=23		ND=15	
MEAN=51		MEAN=39		MEAN=1	
SD=63.6		SD=52.8		SD=-	
BG=0		BG=0		BG=0	

F=6/67
OVERALL MEAN=43.6

1,1,2-TRICHLOROETHANE (ug/1) DL=5

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
60	33A				
N=1		N=0		N=0	
ND=30		ND=28		ND=16	
MEAN=60		MEAN=-		MEAN=-	
SD=-		SD=-		SD=-	
BG=0		BG=0		BG=0	

F=1/75
OVERALL MEAN=60

TRICHLOROETHENE (ug/1) DL=5

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
5	24B	490	1-2A	27	1-12C
100	1-31	1600	1-5A	95	1-12C
47000	1-12B	27	1-6A	48	1-13C
35	1-6B	42	1-5A	110	1-14C
19000	1-12B	2400	1-7A	36	1-15C
130	1-7B	35	1-15A	16	1-15C
45	1-8B	130	1-9A	540	32C
96	1-9B	1100	1-11A	75	33C
16	19B	660	1-12A	1000	34C
300	25B	1100	1-12A	370	34C
210	32A	97	1-13A	25	35C
18000	33A	34	1-14A		
35	1-14B	490	19A		
330000	34A	490	19A		
64	M2	77	20A		
20	1-14B	6900	32B		
		14000	33B		
		30000	34B		
		25000	34B		
		1200	35B		
		170	1-14A		
		440	1-15A		
N=16		N=22		N=11	
ND=15		ND=6		ND=5	
MEAN=25941		MEAN=3931		MEAN=213	
SD=82068		SD=8287		SD=310	
BG=0		BG=0		BG=0	

F=49/75
OVERALL MEAN=10283.3

METHYLENE CHLORIDE (ug/l) DL=5

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
39	M2	9	1-2A	15	33C
11	1-8B	23	1-3A	11	32C
		13	33B	6	34D
		120	1-11A	7	34D
		170	34B	6	34D
N=2		N=5		N=5	
ND=23		ND=11		ND=7	
MEAN=25		MEAN=67		MEAN=9.6	
SD=19.8		SD=73.5		SD=3.6	
BG=0		BG=0		BG=0	

F=12/53
OVERALL MEAN=36.1

VINYL CHLORIDE (ug/1) DL=5

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
120	1-31	530	1-11A	4	34C
23	1-12B	16	25A		
		4	33B		
N=2		N=3		N=1	
ND=29		ND=25		ND=15	
MEAN=71.5		MEAN=183.3		MEAN=4	
SD=68.6		SD=300.3		SD=-	
BG=0		BG=0		BG=0	

F=6/75
OVERALL MEAN=116.2

XYLENE (ug/1) DL=1

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
130	M2	8	1-14A	16	1-10C
6	25B			120	1-14C
38	1-27			530	1-14C
780	1-30				
1659	M1				
496	M3				
74	M4				
205	M6				
2150	MA1				
115	MM2				
N=10		N=1		N=3	
ND=38		ND=29		ND=15	
MEAN=565.3		MEAN=8		MEAN=222	
SD=753.7		SD=-		SD=271.8	
BG=0		BG=0		BG=0	

F=14/96
OVERALL MEAN=451.9

PHENOL (ug/1) DL=5

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
		38	20A		
		86	21A		
N=0		N=2		N=0	
ND=31		ND=26		ND=16	
MEAN=-		MEAN=62		MEAN=-	
SD=-		SD=33.9		SD=-	
BG=0		BG=0		BG=0	

F=2/75
OVERALL MEAN=62

BIS(2-ETHYLHEXYL)PHTHALATE (ug/1) DL=5

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
15	34A	43	20A	1300	25C
70	1-1B	23	21A	19	34C
		7	22A		
		34	19A		
N=2		N=4		N=2	
ND=29		ND=24		ND=14	
MEAN=42.5		MEAN=26.8		MEAN=659.5	
SD=38.9		SD=15.5		SD=905.8	
BG=0		BG=0		BG=0	

F=8/75
OVERALL MEAN=188.9

DI-N-BUTYL PHTHLATE (ug/l) DL=5

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
		300	19A		
		43	20A		
		31	21A		
N=0		N=3		N=0	
ND=31		ND=25		ND=16	
MEAN=-		MEAN=124.7		MEAN=-	
SD=-		SD=152.0		SD=-	
BG=0		BG=0		BG=0	

F=3/75
OVERALL MEAN=124.7

DI-N-OCTYL PHTHLATE (ug/l) DL=5

PERCHED		TOP		REGIONAL	
conc	well	conc	well	conc	well
				37	25C
N=0		N=0		N=1	
ND=31		ND=28		ND=15	
MEAN=-		MEAN=-		MEAN=37	
SD=-		SD=-		SD=-	
BG=0		BG=0		BG=0	

F=1/75
OVERALL MEAN=37

APPENDIX G

ALTERNATIVE
HEALTH ASSESSMENT WORKSHEETS

ALTERNATIVE
HEALTH ASSESSMENT WORKSHEETS

The assessment of health effects at the Building 3001 site has been presented for all contamination observed during the remedial investigation. However, not all of the predicted contamination that creates potential health risks for the population using Tinker AFB water supply wells as a drinking water supply source is attributed to the release from the 3001 Building. Well number 16 (figure 3 of the text) is presently contaminated from uncontrolled releases from the Building 3001 complex and from an unknown source to the northeast of the well. The additional source contributes a large amount of the contaminant concentration to well 16. Long-term predictions of concentrations of contaminants in well 16 from only Building 3001 releases decreased for all indicator chemicals with exception of barium (table G-1). As a result of the decrease in contaminant concentrations, an alternative health assessment was developed to determine the health effects resulting from releases by only the Building 3001 complex (Building 3001 and the fuel storage areas). Presented in this appendix is the tabular data and results of the assessment worksheets to develop hazard indices (HI) of non-carcinogens and the carcinogenic risk characterization of releases from only the Building 3001. The decreased concentrations of well 16 do not impact health risks from the surface water pathway (ingestion and inhalation exposure routes). The lower concentrations predicted over the 70 year evaluation period do change the health impacts evaluated for long-term exposures for that population using the installation water wells as a drinking water source. These impacts are reflected in the alternative assessment worksheets.

TABLE G-1. Present and Predicted Exposure Concentrations of Indicator Chemicals at Soldier Creek and Tinker AFB Water Supply Wells.

	Soldier Creek				Water Supply Wells											
					No. 15				No. 16				No. 17			
			Future			Future				Future				Future		
Contaminant	Present* (ug/l)	10 Year	50-yr (ug/l)	70 Year	Present (ug/l)	10 Year	50-yr (ug/l)	70 Year	Present (ug/l)	10 Year	50-yr (ug/l)	70 Year	Present (ug/l)	10 Year	50-yr (ug/l)	70 Year
Trichloroethene	-	<1	500	600	0.7	3	10	15	1.9	2	2	2	<0.5	5	25	30
Tetrachloroethene	-	3	5	8	<0.5	<0.5	<0.5	<0.5	0.7	1	1	1	<0.5	<0.5	<0.5	<0.5
Benzene	-	<5	<5	<5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	2	3
Hexavalent chromium	-	300	7,000	8,000	5	6	12	13	10	10	12	12	<10	<10	22	20
Lead	-	50	100	120	<10	10	21	21	45	46	51	51	<10	10	21	26
Barium	-	1,000	1,500	1,500	500	601	601	601	680	703	704	704	500	800	801	801
Nickel	-	150	200	200	10	12	21	21	20	21	21	21	<10	10	10	10

* Pathway incomplete at present time; future contamination predicted

Table G-2. Preliminary Release Source Analysis for Baseline Site Conditions.

Release/ Contact Medium	Currently Contaminated	Potential Release Sources	Release Mechanisms	Release Time Frame	Release Likelihood and Amount
Air	No	Contaminated surface water	Volatil-ization	Continuous long-term	Probable low
Surface Water	No	Contaminated groundwater	Seepage	Continuous long-term	Definite moderate
Ground Water	Yes	Contaminated subsurface soil	Percol-ation	Continuous long-term	Definite moderate
Surface Soil	No	None-See Note 1			

Note 1 - Only subsurface soil is contaminated. No further consideration of surface soil as a release/contact medium or source.

Table G-3. Matrix of Potential Exposure Pathways.

Release/ Transport Medium	Exposure Point	Exposure Route	Number of People	Pathway Complete
Groundwater				
Perched	Shallow wells used for non-consumptive domestic use (See note 1.)	Ingestion of irrigated crops	N/A	No
		Inhalation & skin contact from non-consumptive uses	N/A	No
Regional	Workplaces at Tinker AFB	Ingestion of water	22,500 (See note 2.)	Yes
		Inhalation & skin contact from showers and industrial processes	2,500 (See note 3.)	Yes
Surface Water	At and below seepage area to Soldier Creek	Ingestion of aquatic organisms	7,500 (See note 4.)	No
		Dermal contact	5,300 (See note 5.)	No
Air	At and below seepage area to Soldier Creek	Inhalation/ Volatilization from surface water	5,300 (See note 5)	No

Note 1 - Mr. Doug Armstrong of the Oklahoma City-County Health Department on October 14, 1987 stated that his Department had surveyed an area near Tinker and could find no shallow wells using the perched water table for consumptive or non-consumptive uses. No further consideration of perched groundwater as a potential exposure pathway.

Note 2 - This value provided in the Building 3001 Remedial Investigation report (USACE, 1987) and is the total workforce at Tinker. 20,000 of these individuals are exposed for 45 hours per week (four 11-hour workdays) and 2,500 individuals are residents of the base and have continuous exposure.

Note 3 - This value provided in the Building 3001 Remedial Investigation report (USACE, 1987) and is the number of individuals who are residents of Tinker AFB.

Table G-3. Matrix of Potential Exposure Pathways. (Continued)

Release/ Transport Medium	Exposure Point	Exposure Route	Number of People	Pathway Complete

Note 4 - This number provided in census information. It is the number of people who fish in that region of Soldier Creek and was initially assumed to be people under 16 years of age. EPA does not recognize fish consumption by children, so these individuals were assumed to be adults with 70-kg body weight.

Note 5 - This is the number of people who live within 0.5 miles of the stream below the seepage area. It is assumed these individuals use that region of Soldier Creek for contact recreation. Population numbers were developed through census information.

Table G-4. Estimated Short-Term Air Concentrations (ug/cu m).

Chemical	100 m Best Estimate	500 m Best Estimate	100 m Conservative Estimate	500 m Conservative Estimate
Benzene	N/A	N/A	N/A	N/A
Trichloroethene	N/A	N/A	N/A	N/A
Tetrachloroethene	N/A	N/A	N/A	N/A
Nickel	0	0	0	0
Hexavalent Chromium	0	0	0	0
Lead	0	0	0	0
Barium	0	0	0	0

Note 1 - This table for information only. EPA has advised not to use short-term estimates for this RA. Furthermore, short-term contamination of surface water (via groundwater) will not occur and no air contamination through volatilization is possible.

Note 2 - All metals non-volatile at ambient temperature/pressure.

Table G-5. Estimated Short-term Groundwater Concentrations (ug/l).

Chemical	Nearest Residential Well		Nearest Municipal Well Field (Tinker wells)	
	Best Estimate	Conservative Estimate	Best Estimate	Conservative Estimate
Benzene	0	0	<0.5	0.5
Trichloroethene	0	0	1.9	3.8
Tetrachloroethene	0	0	0.7	1.4
Nickel	0	0	25	50
Hexavalent Chromium	0	0	10	20
Lead	0	0	45	90
Barium	0	0	680	1360

Note 1 - Best estimate for nearest municipal well field (Tinker wells) are actual values reported in the Building 3001 Remedial Investigation Report (USACE, 1987).

Note 2 - Conservative estimate is best estimate with a 100% safety factor applied.

Note 3 - No values used for residential wells because no short-term contamination has occurred.

Table G-6. Estimated Long-term Air Concentrations (mg/cu m).

Chemical	100 m Best Estimate	500 m Best Estimate	100 m Conservative Estimate	500 m Conservative Estimate
Benzene	1.0E-6	6.0E-8	3.3E-6	1.2E-7
Trichloroethene	4.0E-4	2.0E-4	4.7E-4	2.7E-5
Tetrachloroethene	4.1E-6	2.4E-7	1.0E-5	4.3E-7
Nickel	0	0	0	0
Hexavalent Chromium	0	0	0	0
Lead	0	0	0	0
Barium	0	0	0	0

Note 1 - All metals non-volatile at ambient temperature/pressure.

Note 2 - Calculation of air concentration at water/air interface made using methodology described in Environmental Science and Technology, November, 1980, pg. 1332. Rate constants of VOC's in the article were used in the first order reaction rate:

$$C(x) = Co\ e^{-kt}$$

Where: C(x) = concentration of contaminant in water following time (t)
Co = the initial concentration of contaminant in water
k = the decay rates developed from the ES&T article
t = time (1ne hour volatilization time was used in computing estimates)

Estimates of air concentration made by converting total quantity (in ug/l) of compound diffused from the water in 1 hour to air concentration, as follows:

ug/l divided by 1000=mg/l=ppm x (molecular weight divided by .02445) = ug/cubic meter divided by 1000 = mg/cubic meter

Estimates of concentration at 100 m and 500 m made using methodology shown in App. A of Environmental Risk Assessment Case Study Handbook:

$$C(x) = \frac{Q}{3.14\ abc}$$

where C(x) =concentration of contaminant at 100 m or 500 m
Q = release rate of substance (mass/time) assume volume=time
a = dispersion coefficient in the lateral direction (distance)
b = dispersion coefficient in the vertical direction (distance)
c = mean wind speed (distance/time)
and a stability level D and wind speed=1 meter/second were assumed

Table G-7. Estimated Long-term Groundwater Concentrations (ug/l).

Chemical	Nearest Residential Well		Nearest Municipal Well Field (Tinker wells)	
	Best Estimate	Conservative Estimate	Best Estimate	Conservative Estimate
Benzene	0	0	0.8	3
Trichloroethene	0	0	12.3	30
Tetrachloroethene	0	0	0.5	1
Nickel	0	0	17.3	21
Hexavalent Chromium	0	0	15.3	22
Lead	0	0	31	51
Barium	0	0	702	801

Note - Residential wells will not be impacted by contaminants during the 70-year evaluation period.

Table G-8. Estimated Long-term Surface Water Concentrations (ug/l).

Chemical	Best Estimate	Conservative Estimate
Benzene	<5	<5
Trichloroethene	500	600
Tetrachloroethene	5	8
Nickel	200	200
Hexavalent Chromium	7000	8000
Lead	100	120
Barium	1500	1500

Note 1 - Best estimate obtained by using 50-year value from modeled data.

Note 2 - Conservative estimate obtained by using 70-year value from modeled data.

Note 3 - Concentration values in the surface water do not reflect dilution making estimates a maximum expected concentration.

Table G-9. Contaminant Concentrations at Exposure Points.

Chemical	Release Medium	Exposure Point	Short-Term Concentration Best Estimate	Short-Term Concentration Conservative Estimate	Long-Term Concentration Best Estimate	Long-Term Concentration Conservative Estimate
Benzene	Air	Soldier Creek	N/A	N/A	1.0E-6	3.3E-6
	Groundwater	Tinker wells	<0.5	0.5	0.8	3.0
	Surface water	Soldier Creek	N/A	N/A	<5	<5
Trichloroethene	Air	Soldier Creek	N/A	N/A	4.0E-4	4.7E-4
	Groundwater	Tinker wells	1.9	3.8	12.3	30
	Surface water	SoldierCreek	N/A	N/A	500	600
Tetrachloroethene	Air	Soldier Creek	N/A	N/A	4.1E-6	1.0E-5
	Groundwater	Tinker wells	0.7	1.4	0.5	1
	Surface water	SoldierCreek	N/A	N/A	5	8
Nickel	Air	SoldierCreek	0	0	0	0
	Groundwater	Tinker wells	25	50	17.3	21
	Surface water	Soldier Creek	N/A	N/A	200	200
Hexavalent Chromium	Air	Soldier Creek	0	0	0	0
	Groundwater	Tinker wells	10	20	15.3	22
	Surface water	Soldier Creek	N/A	N/A	7000	8000
Lead	Air	Soldier Creek	0	0	0	0
	Groundwater	Tinker wells	45	90	31	51
	Surface water	Soldier Creek	N/A	N/A	100	120
Barium	Air	Soldier Creek	0	0	0	0
	Groundwater	Tinker wells	680	1360	702	801
	Surface water	Soldier Creek	N/A	N/A	1500	1500

Note - Water values in ug/l, air values in mg/cubic meter.

Table G-10. Comparison of Applicable or Relevant and Appropriate Requirements to Estimated Exposure Point Concentration. (Exposure Point: Seepage area at Soldier Creek - Inhalation).

Chemical	Applicable or Relevant and Appropriate Requirement	Requirement Concentration (mg/cu m)	Projected Exposure Point Concentration (mg/cu m)	Short-term (S) or Long-term (L) Concentration	Concentration: Standard Ratio
Benzene	MAAC	0.03	N/A	S	N/A
			1.0E-6	L	3.3E-8
Trichloroethene	MAAC	5.40	N/A	S	N/A
			4.0E-4	L	1.5E-6
Tetrachloroethene	MAAC	3.35	N/A	S	N/A
			4.1E-6	L	1.2E-8
Nickel	None - See Note 1				
Hexavalent Chromium	None - See Note 1				
Lead	None - See Note 1				
Barium	None - See Note 1				

Note 1 - Volatilization is the only route of air contamination; no dust or fumes. Metals not volatile at ambient temperature and pressure and thus, no ARAR's.

Note 2 - Best estimate value used for long-term concentration in accordance with worksheet instructions from Risk Assessment Case Study Manual.

Note 3 - MAAC are the maximum ambient air concentration under the state of Oklahoma's Air Toxics Program.

Table G-11. Comparison of Applicable or Relevant and Appropriate Requirements to Estimated Exposure Point Concentration. (Exposure Point: Soldier Creek Surface Water - Oral).

Chemical	Applicable or Relevant and Appropriate Requirement	Requirement Concentration (mg/l)	Projected Exposure Point Concentration (mg/l)	Short-term (S) or Long-term (L) Concentration	Concentration: Standard Ratio
Benzene	See Note 1.				
Trichloroethene	See Note 1.				
Tetrachloroethene	See Note 1.				
Nickel	See Note 1.				
Hexavalent Chromium	See Note 1.				
Lead	See Note 1.				
Barium	See Note 1.				

Note 1 - Drinking water ARARs not appropriate because ingestion of fish and skin/water absorption are only exposure mechanisms for this site. No ARAR's for these exposure methods. Risk comparison based on other criterion shown on Table C-29. Air inhalation for seepage area shown on additional worksheet.

Table G-12. Comparison of Applicable or Relevant and Appropriate Requirements to Estimated Exposure Point Concentration. (Exposure Point: Tinker AFB Municipal Waterwells - Oral)

Chemical	Applicable or Relevant and Appropriate Requirement	Requirement Concentration (mg/l)	Projected Exposure Point Concentration (mg/l)	Short-term (S) or Long-term (L) Concentration	Concentration: Standard Ratio
Benzene	MCL	0.005	<0.0005	S	<0.10
			0.0008	L	0.16
Trichloroethene	MCL	0.005	0.0019	S	0.38
			0.0123	L	2.46
Tetrachloroethene	--	--	0.0007	S	--
			0.0005	L	
Nickel	PG	0.015	0.025	S	1.70
			0.0173	L	1.15
Hexavalent Chromium	MCL	0.05	0.01	S	0.20
			0.0153	L	0.31
Lead	MCL	0.05	0.045	S	0.90
			0.031	L	0.62
Barium	MCL	1.0	0.68	S	0.68
			0.70	L	0.70

Note 1 - Best estimate value used for both short- and long-term concentration in accordance with worksheet instructions from Risk Assessment Case Study Manual.

Table G-13. Comparison of Other Criteria, Advisories, and Guidance to Estimated Exposure Point Concentration. (Exposure Point: Seepage Area at Soldier Creek. - Inhalation)

Chemical	Applicable or Relevant and Appropriate Requirement	Requirement Concentration (mg/cu m)	Projected Exposure Point Concentration (mg/cu m)	Short-term (S) or Long-term (L) Concentration	Concentration: Standard Ratio
Benzene	Y	None			
Trichloroethene	Y	None			
Tetrachloroethene	Y	None			
Nickel	Not Applicable				
Hexavalent Chrome	Not Applicable				
Lead	Not Applicable				
Barium	Not Applicable				

Table G-14. Comparison of Other Criteria, Advisories, and Guidance to Estimated Exposure Point Concentration. (Exposure Point: Tinker AFB Municipal Waterwells - Oral).

Chemical	Applicable or Relevant and Appropriate Requirement Available	Other Criterion Being Considered	Value of Criterion (mg/l)	Projected Exposure Point Concentration (mg/l)	Short-term (S) or Long-term (L) Concentration	Concentration: Standard Ratio
Benzene	Y	None				
Trichloroethene	Y	None				
Tetrachloroethene	N	DWHA (Note 1)	6.8	0.0007 0.0005	S (Note 3) L	0.001 0.0001
Nickel	Y	DWHA	0.350	0.025 0.0173	S L	0.0025 0.0049
Hexavalent Chromium	Y	DWHA	0.17	0.01 0.0153	S L	0.06 0.09
Lead	Y	DWHA	0.01 (Note 2)	0.045 0.031	S L	4.5 3.1
Barium	Y	DWHA	1.8	0.068 0.070	S L	0.38 0.39

Note 1 - DWHA criterion are for longer-term or lifetime exposure of a 70-kg adult. This means the short term values are conservative.

Note 2 - Value obtained by extrapolating 20 ug/day to 2 liter/day average adult water intake.

Note 3 - Short-term values shown for information only. EPA has advised not to use short-term estimates for this RA.

Table G-15. Comparison of Other Criteria, Advisories, and Guidance to Estimated Exposure Point Concentration. (Exposure Point: Soldier Creek Surface Water - Inhalation).

Chemical	Applicable or Relevant and Appropriate Requirement Available	Other Criterion Being Considered	Value of Criterion (mg/kg/day)	Projected Exposure Point Concentration	Short-term (S) or Long-term (L) Concentration	Concentration: Standard Ratio
Benzene	N	PF-HEA	5.2E-2	See Note 1.	L	-
Trichloroethene	N	PF-HEA	1.1E-2	"	L	-
Tetrachloroethene	N	PF-HEA	5.1E-2	"	L	-
		AIC	2.0E-2	"	L	-
Nickel	N	AIC	1.0E-2	"	L	-
Hexavalent Chromium	N	AIC	5.0E-3	"	L	-
Lead	N	AIC	1.4E-3	"	L	-
Barium	N	AIC	5.1E-2	"	L	-

Note 1. - Exposure related to bioconcentration factor in aquatic organisms and intake by exposed population. These values will be calculated on following sheets.

Table G-16. Calculate Air Intakes. (Exposure Point - 100 meter radius of seepage areas).

Chemical		Human Intake Factor (cum/kg/day)	Short-term Concentration (mg/cum)	Subchronic Daily Intake (mg/kg/day)	Short-term Duration (year)	Long-term Concentration (mg/cum)	Chronic Daily Intake (mg/kg/day)
Benzene	A	.29	N/A	N/A	N/A	1.0E-6	2.9E-7
	C	.5	N/A	N/A	N/A	1.0E-6	5.0E-7
Trichloroethene	A	.29	N/A	N/A	N/A	4.0E-4	1.2E-4
	C	.5	N/A	N/A	N/A	4.0E-4	2.0E-4
Tetrachloroethene	A	.29	N/A	N/A	N/A	4.1E-6	1.2E-6
	C	.5	N/A	N/A	N/A	4.1E-6	2.1E-6
Nickel	A	.29	N/A	N/A	N/A	0	0
	C	.5	N/A	N/A	N/A	0	0
Hex chromium	A	.29	N/A	N/A	N/A	0	0
	C	.5	N/A	N/A	N/A	0	0
Lead	A	.29	N/A	N/A	N/A	0	0
	C	.5	N/A	N/A	N/A	0	0
Barium	A	.29	N/A	N/A	N/A	0	0
	C	.5	N/A	N/A	N/A	0	0

Note 1 - Best estimate concentration values used in accordance with instructions of SPHEM.

Note 2 - Human Intake Factor calculated using values suggested in SPHEM; volume of air inspired daily equals 20 cubic meters for adults and 5 cubic meters for children and body weight of 70-kg for adults and 10-kg for children.

Note 3 - A designates values for adults, C designates values for children.

Table G-17. Calculate Intake of Contaminated Fish From Surface Water. (Exposure Point - Soldier Creek Below Seepage Area)

Chemical	Fish BCF	Human Intake Factor (kg fish/kg/day)	Short-term Concentration (mg/l)	Subchronic Daily Intake (mg/kg/day)	Short-term Duration (years)	Long-term Concentration (mg/l)	Chronic Daily Intake (mg/kg/day)
Benzene	5.2	0.00009	0	0	-	<5E-3	1.2E-6
Trichloroethene	10.6	0.00009	0	0	-	0.5	4.9E-4
Tetrachloroethene	31	0.00009	0	0	-	5E-3	1.4E-5
Nickel	47	0.00009	0	0	-	0.2	8.5E-4
Hex chromium	16	0.00009	0	0	-	7.0	1.0E-2
Lead	49	0.00009	0	0	-	0.1	4.6E-4
Barium	None						

Note 1 - BCF values for fish obtained from SPHEM.

Note 2 - Calculations for adults only; assumed no consumption of fish by small children.

Note 3 - No short-term concentrations were considered in surface water since the contaminant plume has not reached East Soldier Creek.

Table G-18. Calculate Groundwater Intakes. (Exposure Point - Tinker AFB Municipal Wells).

Chemical		Human Intake Factor (l/kg/day)	Short-term Concentration (ug/l)	Subchronic Daily Intake (ug/kg/day)	Short-term Duration (year)	Long-term Concentration (ugl)	Chronic Daily Intake (ug/kg/day)
Benzene	A	.029	<0.5	7.3E-3	0.5 year	0.8	2.3E-2
	C	.1	<0.5	2.5E-2	0.5 year	0.8	0.08
Trichloroethene	A	.029	1.9	5.5E-2	0.5 year	12.3	0.36
	C	.1	1.9	0.19	0.5 year	12.3	1.23
Tetrachloroethene	A	.029	0.7	2.0E-2	0.5 year	0.5	1.4E-2
	C	.1	0.7	0.07	0.5 year	0.5	0.05
Nickel	A	.029	25	0.73	0.5 year	17.3	0.5
	C	.1	25	2.5	0.5 year	17.3	1.73
Hex chromium	A	.029	10	0.29	0.5 year	15.3	0.44
	C	.1	10	1.0	0.5 year	15.3	1.53
Lead	A	.029	45	1.3	0.5 year	31	0.90
	C	.1	45	4.5	0.5 year	31	3.10
Barium	A	.029	680	20.7	0.5 year	701	20.3
	C	.1	680	68.0	0.5 year	701	70.1

Note 1 - Amount of water ingested daily and average body weights obtained from values suggested in SPHEM. 2 liters daily for adults and 1 liter daily for children; average body weight for adults is 70-kg and for children is 10 kg. intakes in ug/kg/day.

Note 2 - A designates values for adults, C designates values for children.

Table G-19. Pathways Contributing to Total Exposure.

Exposure Point	Exposure Pathways Contributing to Total Exposure	Comments
1. Soldier Creek at and below seepage area.	Air Inhalation	Long-Term only
	Fish Ingestion	Adult and long-term only
	Dermal Absorption	Not quantified Long-term only
2. Residents/workers at Tinker AFB	Ground-water ingestion	Short- and long-term
	Dermal absorption	Not quantified
	Air Inhalation	Not quantified

Table G-20. Total Subchronic Daily Intake (SDI) Calculation. (Total Exposure Point: Seepage area on Soldier Creek - Oral. Number of People: 7500).

Chemical	Ground-Water SDI	Surface Water SDI	Fish Ingestion SDI	Total Oral SDI	Total Air SDI
Benzene	N/A	N/A	N/A	N/A	N/A
Trichloroethene	N/A	N/A	N/A	N/A	N/A
Tetrachloroethene	N/A	N/A	N/A	N/A	N/A
Nickel	N/A	N/A	N/A	N/A	N/A
Hex Chromium	N/A	N/A	N/A	N/A	N/A
Lead	N/A	N/A	N/A	N/A	N/A
Barium	N/A	N/A	N/A	N/A	N/A

Note 1 - N/A is Not applicable. No short term exposure at this exposure point.

Table G-21. Total Subchronic Daily Intake (SDI) Calculation. (Total Exposure Point: Soldier Creek below Seepage Area. Number of People: 7500).

Chemical	Ground-Water SDI	Surface Water SDI	Fish Ingestion SDI	Total Oral SDI	Total Air SDI
Benzene	N/A	N/A	N/A	N/A	N/A
Trichloroethene	N/A	N/A	N/A	N/A	N/A
Tetrachloroethene	N/A	N/A	N/A	N/A	N/A
Nickel	N/A	N/A	N/A	N/A	N/A
Hex Chromium	N/A	N/A	N/A	N/A	N/A
Lead	N/A	N/A	N/A	N/A	N/A
Barium	N/A	N/A	N/A	N/A	N/A

Note 1 - N/A is Not applicable. No short term exposure at this exposure point.

Table G-22. Total Subchronic Daily Intake (SDI) Calculation. (Total Exposure Point: Tinker AFB municipal wells. Number of People: 22,500).

Chemical	Ground-Water SDI	Surface Water SDI	Fish Ingestion SDI	Total Oral SDI	Total Air SDI
Benzene	7.3E-6	0	0	7.3E-6	0
Trichloroethene	5.5E-5	0	0	5.5E-5	0
Tetrachloroethene	2.0E-5	0	0	2.0E-5	0
Nickel	7.3E-4	0	0	7.3E-4	0
Hex Chromium	2.9E-4	0	0	2.9E-4	0
Lead	1.3E-3	0	0	1.3E-3	0
Barium	1.9E-2	0	0	1.9E-2	0

Note 1 - Adult exposure values only calculated.

Note 2 - Exposure periods differ between 2,500 residents of installation and 20,000 workers. Longer period for residents applied to both workers and residents, which increases conservative nature of estimate.

Note 3 - All values in mg/kg/day.

Table G-23. Total Chronic Daily Intake (CDI) Calculation. (Total Exposure Point: Soldier Creek at and below seepage area. Number of People: 7,500).

Chemical	Ground-Water CDI	Surface Water CDI	Fish Ingestion CDI	Total Oral CDI	Total Air CDI
Benzene	0	0	1.0E-6	1.0E-6	2.9E-7
Trichloroethene	0	0	5.0E-4	5.0E-4	1.2E-4
Tetrachloroethene	0	0	1.4E-5	1.4E-5	1.2E-6
Nickel	0	0	8.7E-4	8.7E-4	0
Hex Chromium	0	0	1.0E-2	1.0E-2	0
Lead	0	0	4.6E-4	4.6E-4	0
Barium	0	0	0	0	0

Note 1 - All values in mg/kg/day.

Note 2 - All assumptions from SPHEM; no consumption of fish by children, adult intake of freshwater fish = 6.5 g/day, and adult body weight = 70 kg.

Note 3 - Ingestion of surface water wat not considered since it is not a treated water supply source. Incidental ingestion was considered a minor component of ingestion and not quantified.

Table G-24. Total Chronic Daily Intake (CDI) Calculation. (Total Exposure Point: Total Exposure Point: Tinker AFB Municipal Waterwells. Number of People: 22,500).

Chemical	Ground-Water CDI	Surface Water CDI	Fish Ingestion CDI	Total Oral CDI	Total Air CDI
Benzene	2.3E-5	0	0	2.3E-5	0
Trichloroethene	3.6E-4	0	0	3.6E-4	0
Tetrachloroethene	1.4E-5	0	0	1.4E-5	0
Nickel	5.0E-4	0	0	5.0E-4	0
Hex Chromium	4.4E-4	0	0	4.4E-4	0
Lead	9.0E-4	0	0	9.0E-4	0
Barium	2.0E-2	0	0	2.0E-2	0

Note 1 - Adult exposure only calculated.

Note 2 - Exposure periods differ between 2,500 residents of installation and 20,000 workers. Longer period for residents applied to both workers and residents, which increases conservative nature of estimate.

Note 3 - All values in mg/kg/day

Note 4 - Dermal and inhalation exposure through showers, dishwashing, etc. not quantified.

Table G-25. Critical Toxicity Values.

Chemical	AIS (mg/kg/day)	AIC (mg/kg/day)	Carcinogenic Potency Factor (mg/kg/day)-1
Inhalation Route			
Benzene	-	-	2.6E-2 (A)
Trichloroethene	-	-	4.6E-3 (B2)
Tetrachloroethene	-	-	1.7E-3 (B2)
Ingestion Route			
Benzene	-	-	5.2E-2 (A)
Trichloroethene	-	-	1.1E-2 (B2)
Tetrachloroethene	-	2.0E-2	5.1E-2 (B2)
Nickel	2.0E-2	1.0E-2	-
Hex Chromium	2.5E-2	5.0E-3	-
Lead	-	1.4E-3	-
Barium	-	5.1E-2	-

Table G-26. Calculation of Subchronic Hazard Index. (Total Exposure Point: Seepage area on Soldier Creek)

Chemical	Inhalation			Oral		
	SDI	AIS	SDI:AIS	SDI	AIS	SDI:AIS
Benzene	N/A	N/A	N/A	N/A	N/A	N/A
Trichloroethene	N/A	N/A	N/A	N/A	N/A	N/A
Tetrachloroethene	N/A	N/A	N/A	N/A	N/A	N/A
Nickel	N/A	N/A	N/A	N/A	N/A	N/A
Lead	N/A	N/A	N/A	N/A	N/A	N/A
Hex Chromium	N/A	N/A	N/A	N/A	N/A	N/A
Barium	N/A	N/A	N/A	N/A	N/A	N/A

Sum of Inhalation SDI:AIS ratios - N/A
Sum of Oral SDI:AIS ratios - N/A
Sum Total of all ratios - N/A

Note 1 - No short term exposure from at this exposure point.

Table G-27. Calculation of Subchronic Hazard Index. (Total Exposure Point: Tinker AFB Municipal Waterwells).

Chemical	Inhalation			Oral		
	SDI	AIS	SDI:AIS	SDI	AIS	SDI:AIS
Benzene	N/A	N/A	N/A	7.3E-7	-	-
Trichloroethene	N/A	N/A	N/A	5.5E-5	-	-
Tetrachloroethene	N/A	N/A	N/A	2.0E-5	-	-
Nickel	N/A	N/A	N/A	7.3E-4	2.0E-2	3.6E-2
Lead	N/A	N/A	N/A	2.9E-4	-	-
Hex Chromium	N/A	N/A	N/A	1.3E-3	2.5E-2	5.2E-2
Barium	N/A	N/A	N/A	2.0E-2	-	-

Sum of Inhalation SDI:AIS ratios - N/A
Sum of Oral SDI:AIS ratios - 8.8E-2
Sum Total of all ratios - 8.8E-2

Note 1 - All values in mg/kg/day

Table G-28. Calculation of Chronic Hazard Index. (Total Exposure Point: Tinker AFB Municipal Waterwells - Oral).

Chemical	Inhalation			Oral		
	CDI	AIC	CDI:AIC	CDI	AIC	CDI:AIC
Benzene	See Note 1			2.3E-5	-	-
Trichloroethene	See Note 1			3.6E-4	-	-
Tetrachloroethene	See Note 1			1.4E-5	2.0E-2	7.0E-4
Nickel	See Note 2			5.0E-4	1.0E-2	0.05
Lead	See Note 2			9.0E-4	1.4E-3	0.64
Hex Chromium	See Note 2			4.4E-4	5.0E-3	0.09
Barium	See Note 2			2.0E-2	5.1E-2	0.39

Sum of Inhalation CDI:AIC ratios = N/A
Sum of Oral CDI:AIC ratios = 1.17
Sum Total of all ratios = 1.17

Note 1 - Inhalation exposure through showers, etc. not quantified for 2,500 base residents. No inhalation exposure projected for 20,000 base workers who are not residents.

Note 2 - No inhalation exposure for metals.

Table G-29. Calculation of Chronic Hazard Index. (Total Exposure Point: Soldier Creek at and below seepage point).

Chemical	Inhalation			Oral		
	CDI	AIC	CDI:AIC	CDI	AIC	CDI:AIC
Benzene	2.9E-7	-	-	1.0E-5	-	-
Trichloroethene	1.2E-4	-	-	5.0E-4	-	-
Tetrachloroethene	1.2E-6	-	-	1.4E-5	2.0E.2	7.0E-4
Nickel	0	1.0E-2	-	8.7E-4	1.0E-2	8.7E-2
Lead	0	5.0E-3	-	4.6E-4	1.4E-2	3.3E-2
Hex Chromium	0	1.4E-3	-	1.03-2	5.0E-3	2.0
Barium	0	5.1E-2	-	N/A	5.1E-3	-

Sum of Inhalation CDI:AIC ratios = N/A
Sum of Oral CDI:AIC ratios = 2.12
Sum Total of all ratios = 2.12

Note 1 - All values in mg/kg/day

Table G-30. Calculation of Risk From Potential Carcinogens. (Total Exposure Point: Tinker AFB Municipal Wells).

Chemical	Exposure Route	CDI x (mg/kg/day)	Carcinogenic Potency Factor = (mg/kg/day)-1	Route Specific Risk	Total Chemical-Specific Risk
Benzene	Oral	2.3E-5	5.2E-2	1.2E-6	1.2E-6
	Inhalation	0	2.6E-2	0	
Trichloroethene	Oral	3.6E-4	1.1E-2	4.0E-6	4.0E-6
	Inhalation	0	4.6E-3	0	
Tetrachloroethene	Oral	1.4E-5	5.1E-2	7.1E-7	7.1E-7
	Inhalation	0	1.7E-3	0	
Nickel	Oral	5.0E-4	None	0	0
	Inhalation	0	N/A	0	
Lead	Oral	9.0E-4	None	0	0
	Inhalation	0	N/A	0	
Hex Chromium	Oral	4.4E-4	None	0	0
	Inhalation	0	N/A	0	
Barium	Oral	2.0E-2	None	0	0
	Inhalation	0	N/A	0	

TOTAL UPPER BOUND RISK = 5.9E-6

Table G-31. Calculation of Risk From Potential Carcinogens. (Total Exposure Point: Soldier Creek at and below seepage point).

Chemical	Exposure Route	CDI (mg/kg/day)	x Carcinogenic Potency Factor (mg/kg/day)-1	= Route Specific Risk	Total Chemical-Specific Risk
Benzene	Oral	1.0E-6	5.2E-2	5.2E-8	6.0E-8
	Inhalation	2.9E-7	2.6E-2	8.0E-9	
Trichloroethene	Oral	5.0E-4	1.1E-2	5.5E-6	6.1E-6
	Inhalation	1.2E-4	4.6E-3	5.5E-7	
Tetrachloroethene	Oral	1.4E-5	5.1E-2	7.1E-7	7.1E-7
	Inhalation	1.2E-6	1.7E-3	2.0E-9	
Nickel	Oral	8.7E-4	None	0	0
	Inhalation	0	N/A	0	
Lead	Oral	4.6E-4	None	0	0
	Inhalation	0	N/A		
Hex Chromium	Oral	1.0E-2	None	0	0
	Inhalation	0	N/A	0	
Barium	Oral	0	None	0	0
	Inhalation	0	N/A	0	

TOTAL UPPER BOUND RISK = 6.9E-6